БЕЗОПАСНОСТЬ ТЕХНОГЕННЫХ И ПРИРОДНЫХ СИСТЕМ

№2 2019

SAFETY OF TECHNOGENIC AND NATURAL SYSTEMS

n.2 2019

ISSN 2541-9129

DOI 10.23947/2541-9129

Сетевой электронный теоретический и научно - практический журнал

Network Electronic Journal

http://bps-journal.ru/

CONTENT

LABOR PROTECTION

FIRE AND INDUSTRIAL SAFETY

UDC 614.87
DOI 10.23947/2541-9129-2019-2-2-12

DEVELOPMENT OF MICROCLIMATE NORMALIZATION SYSTEM ELEMENTS IN THE CABIN OF TORUM GRAIN HARVESTER

Bulygin Yu. I., Shchekina E. V., Maslenskiy V. V.
Don state technical University, Rostov-on-Don, Russian Federation

bulyur_rostov@mail.ru
n1923@donpac.ru
victor.maslensky@yandex.ru

The working conditions of the combine operator are investigated. It is revealed that the leading occupational hazards of the worker are microclimate adverse parameters. Based on the analysis of the harvester cabin thermal state during summer and winter operation, a system of microclimate normalization is proposed, for which the main functional characteristics — cold and heat capacity — are determined. According to the calculation results, the relationship between these characteristics and the operating speed of the combine is established. Computer modelling of heat and mass transfer in the conditions of active ventilation of the cabin allows us to get a more detailed picture of the formation of streams of air movement and temperature in the working area of the operator and to recommend measures of thermal protection.

Keywords: agriculture, harvester, labor protection, microclimate, harmful factors, climate system.

УДК 614.87
DOI 10.23947/2541-9129-2019-2-2-12

РАЗРАБОТКА ЭЛЕМЕНТОВ СИСТЕМЫ НОРМАЛИЗАЦИИ МИКРОКЛИМАТА В КАБИНЕ ЗЕРНОУБОРОЧНОГО КОМБАЙНА TORUM

Булыгин Ю. И., Щекина Е. В., Масленский В. В.
Донской государственный технический университет, г. Ростов-на-Дону, Российская Федерация
bulyur_rostov@mail.ru
n1923@donpac.ru
victor.maslensky@yandex.ru

Исследованы условия труда оператора комбайна. Выявлено, что ведущими профессиональными вредностями работника являются неблагоприятные параметры микроклимата. На основании анализа теплового состояния кабины комбайна при летнем и зимнем режиме работы предложена система нормализации микроклимата, для которой определены основные функциональные характеристики — холодо- и теплопроизводительность. По результатам расчета установлена взаимосвязь между указанными характеристиками и рабочей скоростью движения комбайна. Компьютерное моделирование тепломассопереноса в условиях активной вентиляции кабины позволяет получить более детальную картину формирования потоков движения воздуха и температуры в рабочей зоне оператора и рекомендовать меры теплозащиты.

Ключевые слова: сельское хозяйство, комбайн, охрана труда, микроклимат, вредные факторы, климатическая система.

Introduction. Agriculture is one of the most promising and rapidly developing economic activities in Russia. Being on the second place in the world in wheat export and being the champion in grain harvest, agriculture provides employment for only 9 % of Russians. In this regard, this sector of the economy is characterized by a relatively low percentage of people working under the influence of dangerous and harmful factors (29.6 %) [1], which should not be a significant problem in terms of labor protection. However, some types of agricultural activities, such as combine harvesting of grain crops, are characterized by an increased level of technosphere hazards. Let us consider them in more detail.

The process of harvesting grain crops by combines includes the following operations: cutting the

plant, its threshing, separating grain from thrashed heap and other impurities [2]. When performing these works, the operator of the combine is influenced by a complex of harmful factors, such as:

acoustic and vibration factors;

labor process factors (severity, intensity);

light environment;

microclimate;

chemical factor and dust.

The above-mentioned occupational hazards during prolonged contact contribute to the occurrence of pathologies of the respiratory system, vision, hearing, cardiovascular system and musculoskeletal system, which can further lead to disability or, without timely diagnosis and treatment, to death [3]. The impact of harmful factors is aggravated by the fact that the operator of the combine is in a confined space of the cabin (only 2-4 m^3). That is why it is important to prevent or minimize their harmful effects on the employee by developing engineering protection systems.

For occupational diseases prevention, the operator of the combine needs a system of technical means that reduce the harmful effects and, as a result, the risk of damage to health. Modern harvesters are equipped with most of such tools. For example, noise reduction in the cab is often achieved by using an acoustic screen placed between the cab and the engine. The screen is made of a steel sheet with a thickness of 1 mm and is situated at the edges of the engine with a sound-absorbing layer with a thickness of 10-15 mm. Acoustic efficiency of such a screen does not exceed 7 dB. Silencers are used to reduce more intense noise [4]. Heat flows into the cabin of the combine from the engine and transmission are reduced by its form - a single capsule with separation from the engine compartment and transmission. Such design together with the vibration of the cab not only provides thermal protection to the operator, but the reduction in noise levels and vibration.

Achieving a comfortable level of natural light in the cabin for the operator of the combine is not difficult and is carried out by windows tinting. As a result, they acquire the ability to reflect sun rays.

Tinted glass of the harvester cabin is also a passive means of thermal protection, used along with the insulation of the walls. However, these means of protection are often insufficient when the temperature difference in and out of the cabin is 20-25°C. Therefore, the air in the cabin is further cooled to the optimum temperature by ventilation or air conditioning system. At the same time, the excess pressure created by the fan or by the air conditioner ensures that dusty and contaminated air does not get into the cabin [5].

Setting goals and objectives. The purpose of the study is to calculate the basic elements of the climate system for the cabin of TORUM combine harvester.

Objectives:

To determine heat gain and heat loss, as well as the parameters and the amount of air supplied to the cabin, taking into account the range of operating speeds of the combine. It should be noted that the climate system in operation (summer mode — +45°C, winter mode — -20°C) should provide a decrease/increase in the temperature in the cabin to the comfortable temperature of +24°C in the workplace.

To calculate the climate system main elements in the cabin — condenser cooling system and the

evaporator of the air heating system.

To evaluate the efficiency of the climate system as a whole.

Main part. 1) The calculation of heat gain and heat loss started by determining the value of the heat transfer coefficient K (W/(m^2·K)), depending on the thermal conductivity coefficient of the wall λ (W/(m·K)), its thickness δ (m) and the heat transfer coefficient α (W/(m^2·K)) for the outer and inner surface of the wall [6]:

$$K = \frac{1}{\sum\frac{\delta}{\lambda} + \frac{1}{\alpha_{н}} + \frac{1}{\alpha_{в}}} \qquad 1)$$

K coefficient was determined for four types of walls of the harvester cabin: end and side walls, floor and roof. In this case, it was taken into account the fact that almost all walls, except the front end and side, have a multilayer heterogeneous structure due to insulating and cladding materials.

The coefficient for the outer surface of the wall was calculated based on the range of operating speeds of the combine U (m/s) and the length of its cabin l (m):

$$\alpha_{н} = 15 + \frac{3U}{l^{0,2}}. \qquad 2)$$

For the inner wall surface the coefficient α was taken according to the recommendations [7] equal to 10 W/(m^2·K). The initial data for the calculation and the calculation results are presented in table 1.

Table 1

Initial data for calculation and calculation results of the coefficient K

<table>
<tr><th rowspan="2">No.</th><th rowspan="2">Wall type</th><th rowspan="2">Layer material</th><th rowspan="2">λ, W/(m·K)</th><th rowspan="2">δ, m</th><th colspan="3">K coefficient, W/(m²·K), at combine speed U, km/h</th></tr>
<tr><th>0</th><th>10</th><th>20</th></tr>
<tr><td rowspan="3">1</td><td rowspan="3">Floor</td><td>steel</td><td>47</td><td>0.002</td><td rowspan="3">1.76</td><td rowspan="3">1.83</td><td rowspan="3">1.87</td></tr>
<tr><td>felt</td><td>0.04</td><td>0.015</td></tr>
<tr><td>rubbermat</td><td>0.16</td><td>0.004</td></tr>
<tr><td rowspan="3">2</td><td rowspan="3">Ceiling</td><td>steel</td><td>47</td><td>0.002</td><td rowspan="3">1.82</td><td rowspan="3">1.89</td><td rowspan="3">1.92</td></tr>
<tr><td>felt</td><td>0.04</td><td>0.015</td></tr>
<tr><td>upholstery leather</td><td>0.15</td><td>0.002</td></tr>
<tr><td rowspan="3">3</td><td rowspan="3">Rear end wall</td><td>steel</td><td>47</td><td>0.002</td><td rowspan="3">1.82</td><td rowspan="3">1.89</td><td rowspan="3">1.92</td></tr>
<tr><td>felt</td><td>0.04</td><td>0.015</td></tr>
<tr><td>upholstery leather</td><td>0.15</td><td>0.002</td></tr>
<tr><td>4</td><td>Front end wall</td><td>glass</td><td>0.85</td><td>0.005</td><td>5.56</td><td>6.67</td><td>7.14</td></tr>
<tr><td>5</td><td>Side walls</td><td>glass</td><td>0.85</td><td>0.005</td><td>5.56</td><td>6.67</td><td>7.14</td></tr>
</table>

To find heat gain ways in the cabin and their further calculations we have considered thermodynamic system pictured in Fig. 1.

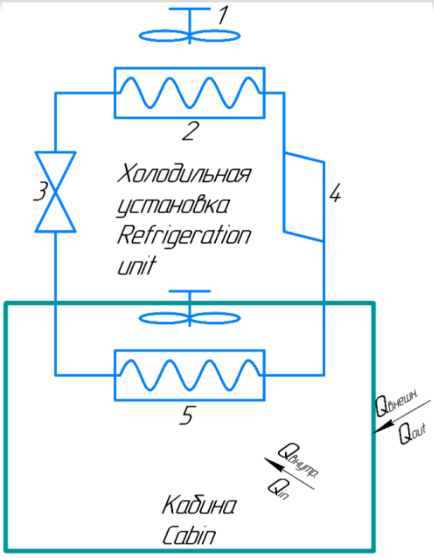


Fig. 1. Thermodynamic system "cabin-refrigeration unit"

The purpose of the main elements of the refrigeration unit is as follows. The compressor 4 increases the pressure of the vaporous refrigerant — freon R134a. In the condenser 2, freon, cooled by the fan 1, passes into the liquid phase at a constant temperature. Temperature control valve 3 is used to reduce the pressure of the liquid refrigerant by throttling to a pressure at which freon boils in the evaporator 5. In the evaporator, freon passes into a vaporous state, taking away from the environment (the air of the combine cabin) the latent heat of vaporization. Refrigerant vapor goes to the compressor. After this, the cycle repeats itself.

Heat gain into the cab of the harvester according to fig. 1 is from inner sources $Q_{внутр}$. (from the operator and his assistant; from lighting and electrical equipment) and from sources located outside the cabin $Q_{внешн}$. (from outside air through fences and from infiltration; from solar radiation).

The calculation of heat gain was made in accordance with the formulas:

through the fence Q_1, W:

$$Q_1 = \Sigma K_i \cdot F_i (t_н - t_в),$$

3)

where F_i — the area of the cabin wall, m^2, was determined by Fig. 2; $t_н$ — the temperature outside the cabin, °C; $t_в$ — the temperature inside the cabin, °C.

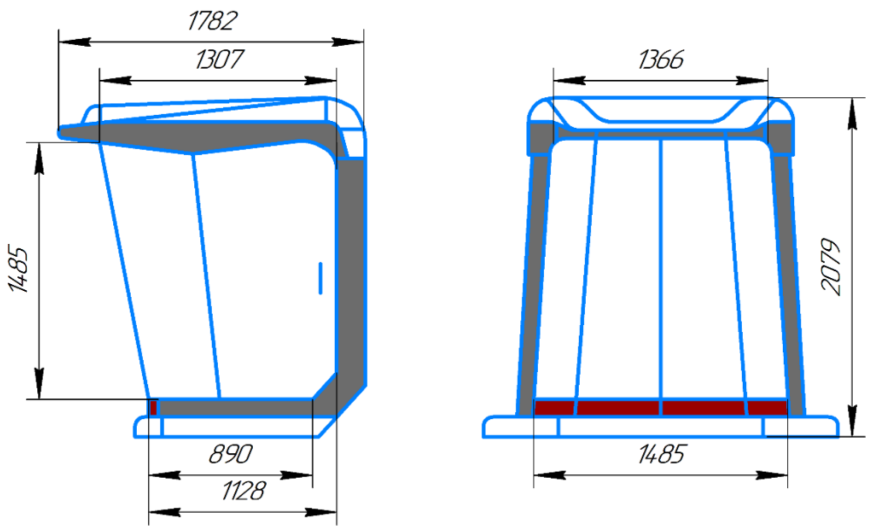


Fig. 2. Geometric dimensions of the cab of TORUM combine harvester from the infiltration of Q_2, W:

$$Q_2 = k \cdot Q_1,$$ 4)

where k is a dimensionless coefficient equal to 0.3.

from the combine operator and his assistant Q_3, W:

$$Q_3 = q_1 \cdot n, \tag{5}$$

where q_1 is the heat transfer of one person equal to 117 W; n is the number of people in the cabin.

from lighting and electrical equipment, the heat input Q_4 was taken to be 47 W [6].

from solar radiation Q_5, W:

$$Q_5 = \frac{A_к \cdot I \cdot K_к \cdot F_к}{\alpha_н} + I \cdot K_{ок} \cdot F_{ок}, \tag{6}$$

where $A_к$ — the coefficient of sunlight heat absorption by the cabin roof, equal to 0.5; I — the intensity of solar radiation, equal to 950 W/m^2; $K_к$ — the coefficient of heat transfer of the roof, W/(m^2·K); $K_{ок}$ — the coefficient of sunlight transmission by glass, equal to 0.1; $F_к$ and $F_{ок}$ — the area of the roof and windows on the side wall, m^2; $\alpha_н$ — the coefficient of heat transfer from the air to the outer surface of the wall, which was determined by the formula:

$$\alpha_н = 8 + \frac{0{,}7 \cdot (U + 15)}{l^{0,2}}. \tag{7}$$

The calculation results are shown in table 2.

Table 2

Calculation results of the total heat gain Q_Σ

No.	Heat gain type	Value Q, Вт, at the speed of the combine U, km/h		
		0	10	20
1	Through the fence Q_1	852.02	989.68	1048.29
2	From the infiltration Q_2	255.61	296.90	314.49
3	From the combine operator and his assistant Q_3	234		
4	From lighting and electrical equipment Q_4	47		
5	From solar radiation Q_5	408.39	403.38	397.61
6	Total heat gain Q_Σ	1797.02	1970.96	2041.39

The amount of outside air that must be supplied to the harvester cabin to assimilate the excess heat and reduce the temperature to the optimum +24 °C:

$$G = \frac{Q_\Sigma}{c_p \cdot (t_к - t_{ox})}, \tag{8}$$

where c_p — specific heat of air, equal to 1.01 kJ/(kg·°C); $t_к$ — the optimum temperature in the cabin, °C; t_{ox} — the temperature of the cooled air, °C, supplied directly to a person was estimated to be equal to 3-5 °C below $t_к$ to prevent cold-related diseases.

To assess the operation of the air conditioning system in the cabin of the combine, its main functional characteristics were determined [8]:

cooling capacity Q_o, kW:

$$Q_0 = \rho_{ox} G(I_н - I_{ox}), \tag{9}$$

where ρ_{ox} is the density of the cooled air, kg/m^3; $I_н$ and I_{ox} — the enthalpy of the outside and cooled air, respectively, kJ/kg.

the mechanical power consumption N_o, kW, was assumed to be 2.

cooling coefficient η_o:

$$\eta_0 = \frac{Q_0}{N_o}. \tag{10}$$

The calculation results are presented in table 3.

Table 3

Calculation results of the main parameters of the air conditioning system

No.	Parameter	Value of the parameter at the speed of the combine U, km/h		
		0	10	20
1	Air flow for cooling G_{ox}, m^3/h	593.08	650.48	673.73
2	Cooling capacity Q_o, kW	4.96	5.44	6.77
3	Mechanical power consumption N_o, kW	1.8	2	2.1
4	Cooling coefficient η_o	2.76	2.72	3.22

Heat loss in the cabin of the combine is:
through the fence Q_1, W, similar to the formula (3);
from infiltration Q_2, W, similar to the formula (4);
from random losses Q_3, W, was taken by default equal to 0;
from evaporation of snow or ice on the surface of the cabin Q_4, W:

$$Q_4 = \frac{n \cdot r_п \cdot m_п}{3600}, \qquad 11)$$

where n is the number of passengers; $r_п$ is the rate of vapor release per person; $m_п$ is the amount of vapor exhaled by a person.

The calculation results are shown in table 4.

Table 4

Calculation results of the total heat loss Q_{Σ}

No.	Type of heat loss	Value Q, W, at the speed of the combine U, km/h		
		0	10	20
1	Through the fence Q_1	1785.18	2073.61	2196.40
2	From infiltration Q_2	535.55	622.08	658.92
3	From infiltration Q_3	0		
4	From evaporation of snow or ice on the cab surface Q_4	97.22		
5	Total heat loss Q□	2417.95	2792.91	2952.54

The amount of outside air that must be supplied to the harvester cabin to raise the temperature to the optimum +24 °C:

$$G = \frac{Q_{\Sigma}}{c_p \cdot \rho_н (t_н - t_к)}, \qquad 12)$$

where $\rho_н$ is the density of the heated air, kg/m^3; $t_к$ is the optimal temperature of the air in the cabin, °C; $t_н$ is the temperature of the heated air, °C, which is taken to be 40-45 °C according to the hygienic standards.

To assess the operation of the harvester cabin heating system, its main functional characteristic was determined – the heat capacity $Q_{от}$, kW, in full recirculation mode [8]:

$$Q_{от} = c_p \cdot \rho_н \cdot G(t_н - t_к), \qquad 13)$$

The calculation results are presented in table 5.

Table 5

Calculation results of the main parameters of the heating system

No.	Parameter	Value of the parameter at the speed of the combine U, km/h		
		0	10	20
1	Air flow for heating $G_{от}$, m^3/h	124.69	144.02	152.26
2	Heat capacity $Q_{от}$, kW	2.42	2.79	2.95

Thus, the above calculation showed that such a parameter as the speed of the combine is one of the most affecting the value of the cooling and heat capacity of the microclimate normalization system in the cabins of self-propelled machines. The calculations showed (Fig. 3) that the increase in the speed of the combine from 0 to 10 km/h led to an increase in cooling capacity by 10 %, and heat capacity — by 15 %. With a further increase in the speed from 10 to 20 km/h, the cooling capacity increases by 26 %, the heat capacity by 7 %. At the same time, the standard air conditioning system of the combine is designed for a cooling capacity of not more than 5.6 kW, which is not enough to ensure an acceptable microclimate in the combine workplace (Fig. 3).

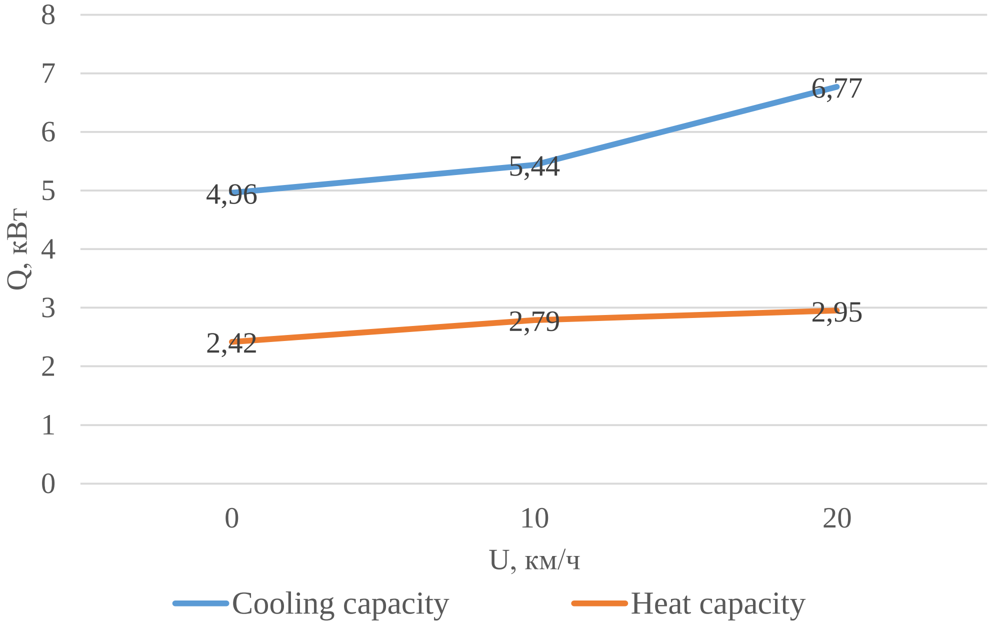


Fig. 3. Curve of the cooling and heat capacity Q of the climate system on the speed U of the harvester

2) The calculation of the capacitor is reduced to the determination of its surface area F, m^2:

$$F = \frac{Q}{K \cdot \theta_{cp}}, \qquad 14)$$

where Q is the thermal load on the capacitor, W; K is the heat transfer coefficient of the capacitor wall, $W/(m^2{\cdot}K)$; θ_{cp} is the average logarithmic temperature difference, K.

The thermal load on the air cooler Q, W, is equal to the sum of the cooling capacity Q_o, W, and the power of the compressor $N_к$, W, required to eliminate excess heat:

$$Q = Q_o + N_к. \qquad 15)$$

The value Q at the maximum speed of the combine was 8.87 kW.

The heat transfer coefficient of the condenser wall K was calculated by the formula (16) and amounted to 166.67 $W/(m^2{\cdot}K)$.

$$K = \frac{1}{\frac{1}{\alpha_{вн}} + \frac{\delta}{\lambda} + \frac{1}{\alpha_{нар} \cdot K_{реб}}}, \qquad 16)$$

where δ — the thickness of the condenser wall, m; λ — the coefficient of thermal conductivity of the wall, W/(m·K); $\alpha_{вн}$ and $\alpha_{нар}$ — the coefficient of heat transfer of the refrigerant inside the condenser and the air outside, W/(m^2·K); $K_{реб}$ — the degree of ribbing of the condenser.

The average logarithmic temperature difference $\theta_{ср}$, was determined according to the outdoor temperatures and cooled air $t_{нар}$ и $t_{ох}$, °C, and the condensation temperature of the refrigerant $t_к$, °C which was taken 8°C above $t_{нар}$ [9]:

$$\theta_{ср} = \frac{t_{нар} - t_{ох}}{\ln \frac{t_к - t_{ох}}{t_к - t_{нар}}}; \qquad 17)$$

The $\theta_{ср}$ value was 37.5 °C.

The surface area of the capacitor according to the formula (14) is 1.42 m^2.

The calculation of the evaporator is also reduced to the determination of its surface area F, m^2:

$$F = \frac{Q}{K \cdot [T_к - (T_{нар} - T_{наг})/2]}, \qquad 18)$$

where Q is the thermal load on the evaporator, W; K is the heat transfer coefficient of the evaporator wall, W/(m^2·K); $T_{наг}$ is the temperature of the heated air, K.

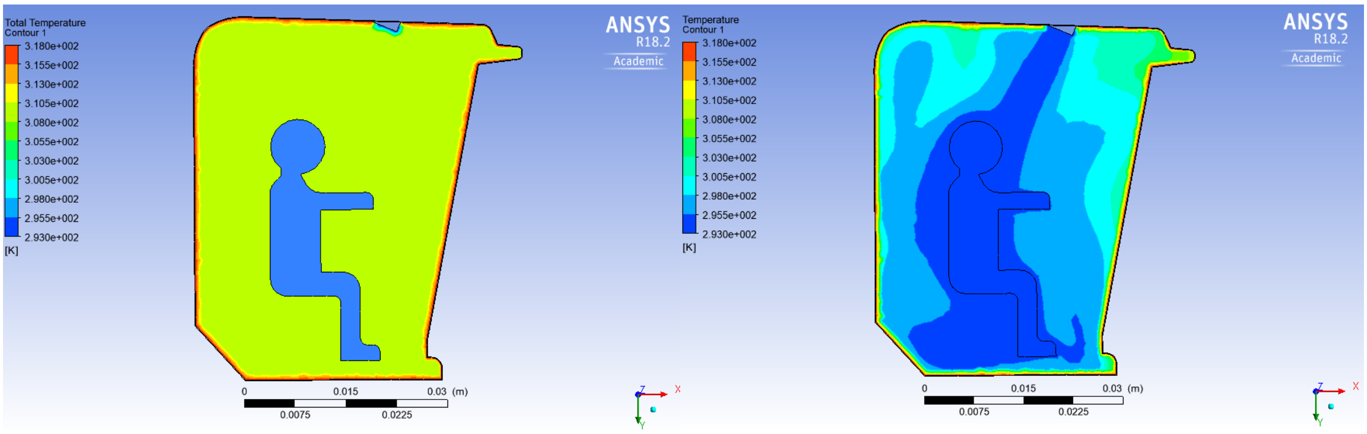
The thermal load on the evaporator Q is equal to the heat capacity of the heating system and amounted to 2950 watts.

The heat transfer coefficient of the evaporator wall K was chosen to be 40.71 W/(m^2·K) [10], taking into account the recommended velocity of the refrigerant vapor through the evaporator tube equal to 5.9 m/s.

The surface area of the evaporator according to the formula (18) is 1.39 m^2.

3) To obtain a more detailed picture of the impact of adverse microclimate on the operator, a simulation of the thermal state of the harvester cabin was carried out using the optimization system of engineering calculations — ANSYS, namely the Fluid Flow plug-in (CFX), which allows you to obtain high-quality models of hydrogasdynamic systems.

The initial data for the simulation were the results of calculations of the heat balance of the harvester cabin. The simulation results are shown in Fig. 4-7.



a) b)

Fig. 4. Temperature profile of the air in the cabine in the summer without the climate system (a); with the climate system (b)

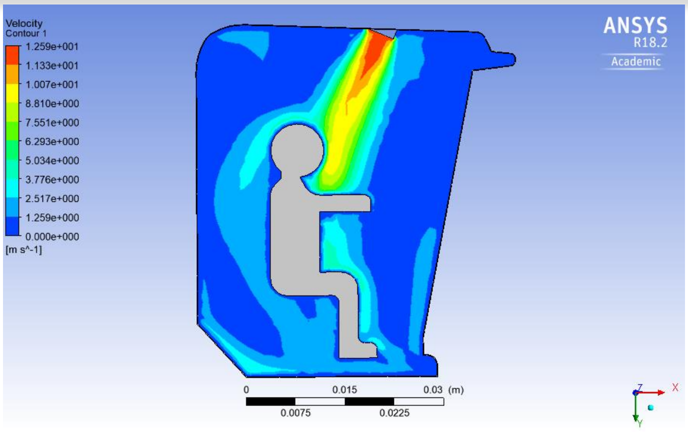
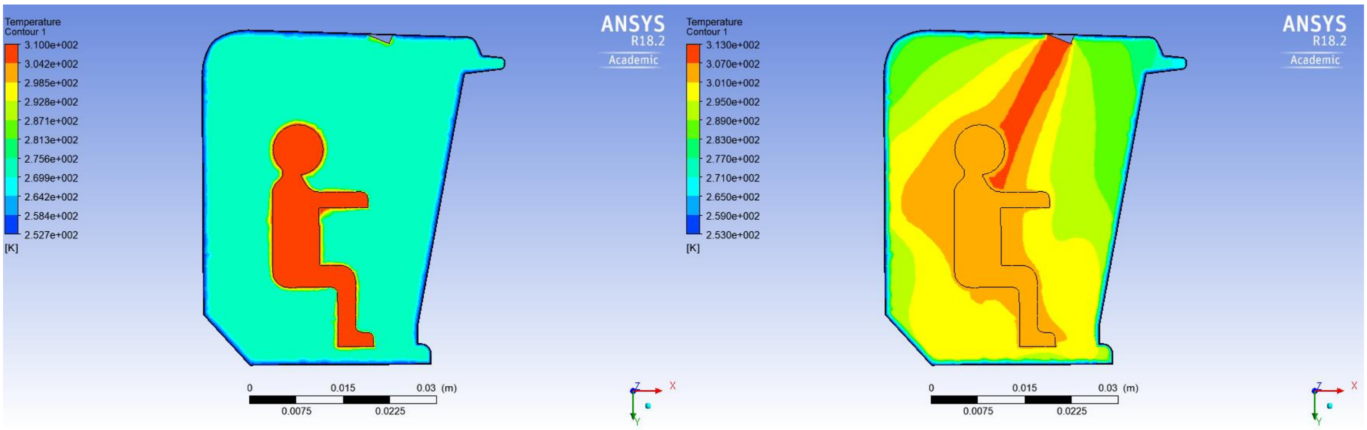


Fig. 5. Profile of air speed in the combine cabin in the summer mode of operation with a working climate system



a) b)

Fig. 6. Profile of the air temperature in the combine cabin in
the winter mode without the climate system (a); with the operating climate system (b)

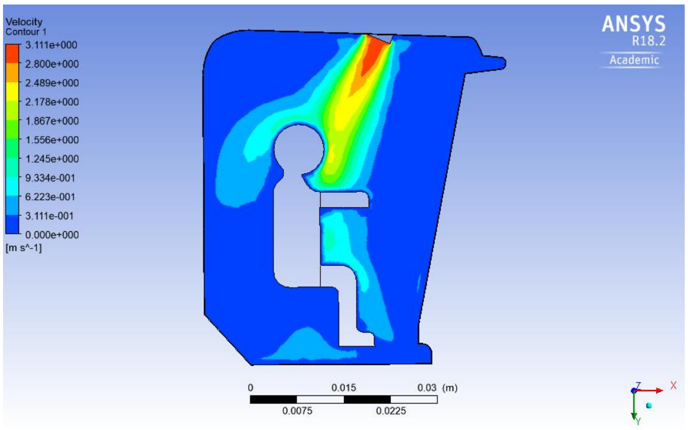


Fig. 7. Profile of air speed in the combine cabin in the winter mode of operation with the operating climate system

As it can be seen from the calculation results (Fig. 4-7), the operation of the selected climate system is effective, since it provides comfortable air temperatures in the cabin of the combine at different modes (in different periods of the year) not exceeding +24 °C.

Conclusion.

The approximate engineering calculation of heat gain and heat loss according to the known method [6] is made, the parameters and the amount of air supplied to the cabin are determined, the values of the surface areas of the main elements of the microclimate normalization system are obtained.

Computer modelling of heat and mass transfer in the conditions of active ventilation of the cabin allows you to get a more detailed picture of the formation of streams of air movement and temperature in the working area of the operator and to recommend thermal protection measures.

In the future for a reasonable and final selection of the main equipment of the air conditioning system for the cab of the Torum combine is planned:

to make a scheme of air treatment;

to determine the thermal load on the main equipment of air conditioners, taking into account air recirculation;

to make calculation and selection of the main equipment of air conditioning system for combine cabins taking into account the length of refrigerant hoses;

to perform calculation and selection of the main equipment of the air conditioning system of the harvester cabins, when variable capacity Denso 7SBU16C is used in the compressor system.

References

1. Trud i zanyatost' v Rossii. 2017: stat. sb. pod red K.E. Laykam. [Labor and employment in Russia. 2017: coll. of articles ed. by K. E. Laykam.] Moscow: Rosstat, 2017, 261 p. (in Russian).

2. Solntsev, V.N., Tarasenko, A.P., Orobinskiy, V.I. et al. Mekhanizatsiya rastenievodchestva. Uchebnik. [Mechanization of crop production. Textbook.] Moscow: INFRA-M, 2017, 383 p. (in Russian).

3. Maslenskiy, V.V., Bulygin, Yu.I., Shchekina, E.V. Prognozirovanie professional'nogo riska ushcherba zdorov'yu rabotayushchikh v kontakte s vedushchimi vrednymi faktorami liteynogo proizvodstva. [Prediction of professional risk injury working with leading harmful factors of the foundry.] Ekologiya i bezopasnost' v tekhnosfere: sovremennye problemy i puti resheniya: sb. tr. Vserossiyskoy nauc.-prakt. konf. molodykh uchenykh, aspir. i stud. [Ecology and safety in the technosphere: modern problems and solutions: Proc. of All-Russian sci.-pract. conf. of young scientists, postgraduates and stududents.] Tomsk: TPU Publishing house, 2018, pp. 305-309 (in Russian).

4. Meskhi, B.Ch. Uluchenie usloviy truda operatorov kombaynov za schet snizheniya shuma I vibratsii: dis. kand. tekhn. nauk. [Improvement of working conditions of combine operators by reducing noise and vibration: Ph.D. thesis in Engineering Science.] Rostov-on-Don, 1999, 132 p. (in Russian).

5. Guseva, S.V. Issledovanie i uluchshenie mikroklimata v kabine zernouborochnogo kombayna: dis. kand. tekhn. nauk. [Research and improvement of microclimate in the cabin of combine harvester: Ph.D. thesis in Engineering Science.] Moscow, 1974, 170 p. (in Russian)

6. Ustinov, A.S., Savin, I.K. Teplotekhnika: ucheb.-metod. Posobie. [Heat engineering: study guide.] Petrozavodsk: Izdatel'stvo PetrGU, 2010, 20 p. (in Russian).

7. SanPiN 4616-88. Sanitarnye pravila po gigiene truda voditeley avtomobiley. Utv. Postanovleniem sanit. Vracha SSSR ot 05.05.1998 No. 4616-88. [SanPiN 4616-88. Sanitary rules on occupational health of car drivers. Approved by the resolution of sanitary inspector of the USSR of 05.05.1988 No. 4616-88.] Sbornik vazhneyshikh ofitsial'nykh materialov po sanitarnym i protivoepidemicheskim voprosam. [Coll. of the most important official materials on sanitary and anti-epidemic issues.] Vol. 1, part 2, Moscow, 1991 (in Russian).

8. Mikhaylov, V.A., Sharipova, N.N. Sredstva normalizatsii mikroklimata i ozdorovleniya vozdushnoy sredy v kabinakh traktorov: ucheb. posob. [Means of normalization of microclimate and improvement of air environment in the cabs of tractors: study guide.] Moscow: MAMI, 2002, 90 p. (in Russian).

9. Kholodil'naya tekhnika. Konditsionirovanie vozdukha. Svoystva veshchestv: sprav. pod red. S.N. Bogdanova. 4-e izd. pererab. i dop. [Refrigeration equipment. Air conditioning. Properties of substances: ref. under the editorship of S.N. Bogdanov. 4-th edition, revised and added.]. Saint Petersburg:

SPbGAKHPT, 1999, 320 p. (in Russian).

10. Vnytrennie sanitarno-tekhnicheskie ustroystva, pod red. I.G. Staroverova. 2-e izd. pererab. i dop. [Internal sanitary-technical devices, ed. by I. G. Staroverov. 2-nd ed. revised and added] Moscow: Stroyizdat, 19, 502 p. (in Russian).

Received 05.05.2019
Submitted 06.05.2019
Scheduled in the issue 05.06.2019

Autors:

Bulygin Yuriy Igorevich,
professor of the Department "Life Safety and Environmental Protection», Don State Technical University, (1, Gagarin sq., Rostov-on-Don, 344000, Russia), Doctor of techn. sciences,
bulyur_rostov@mail.ru

Shchekina Ekaterina Viktorovna,
associate professor of "Life Safety and Environmental Protection» department, Don State Technical University, (1, Gagarin sq., Rostov-on-Don, 344000, Russia), professor,
n1923@donpac.ru

Maslenskiy Viktor Valeryevich,
Master's degree student of "Life Safety and Environmental Protection» department Don State Technical University, (1, Gagarin sq., Rostov-on-Don, 344000, Russia),
victor.maslensky@yandex.ru

UDC 613.6
DOI 10.23947/2541-9129-2019-2-13-17

ANALYSIS OF POTENTIAL HAZARDS WHILE WORKING WITH TRUCK MIXER

Teplyakova S. V., Kotesova A. A., Nedoluzhko A.I.
Don state technical University, Rostov-on-Don, Russian Federation

svet-tpl@yandex.ru
a.kotesova@mail.ru
alexsander1948@yandex.ru

The paper considers hazards of production factors and engineering solutions to labor protection based on physical laws taking into account new solutions of scientific and technical progress. This study will allow implementing labor protection measures in design and development, as well as in industries. The development and implementation of safe equipment, safe methods and types of work includes a wide range of solutions that can ensure the safety of certain types of work, improve working conditions. The paper considers these issues on the example of the design and operation of a mixer truck.

Keywords: risk factors hazards, prediction, engineering solutions, labor protection, development and introduction of safe equipment, mixer truck.

УДК 613.6
DOI 10.23947/2541-9129-2019-2-13-17

АНАЛИЗ ПОТЕНЦИАЛЬНЫХ ОПАСНОСТЕЙ ПРИ РАБОТЕ АВТОБЕТОНОСМЕСИТЕЛЯ

Теплякова С. В., Котесова А. А., Недолужко А. И.
Донской государственный технический университет, г. Ростов-на-Дону, Российская Федерация
svet-tpl@yandex.ru
a.kotesova@mail.ru
alexsander1948@yandex.ru

С учетом новых решений научно-технического прогресса изучаются опасности производственных факторов, разрабатываются инженерные решения охраны труда на основе физических законов. Настоящее исследование позволит внедрить мероприятия по охране труда в проектно-конструкторских разработках, а также в условиях производства. Разработка и внедрение безопасной техники, безопасных приемов и видов работ включает в себя широкий круг решений, которые позволяют обеспечить безвредность выполнения тех или иных видов работ, улучшить условия труда. В данной работе эти вопросы рассмотрены на примере конструкции и функционирования автобетоносмесителя.

Ключевые слова: опасности производственных факторов, прогнозирование, инженерные решения, охрана труда, разработка и внедрение безопасной техники, автобетоносмеситель.

Introduction. The development of science and technology has led to the fact that the person during work is now practically freed from high physical activity, as the working bodies of machines do the hardest physical part. On the other hand, the complexity of the process of controlling the equipment, increase in the amount of simultaneously incoming information on the work of the machine increase the neuropsychic load on the operator.

Analysis of potential hazards while working with truck mixer. Analyzing the operation of a truck mixer, it is possible to distinguish a number of the following hazards for the operating personnel health [1, 2]:

• hazard from rotating elements, which, in addition to the parts that transmit motion, include a mixing drum rotating during the concrete mixture preparation. The rotation of these elements and the operation of the car engine lead to noise;

• vibration sources similar to noise sources. In case of uneven operation of the engine, the wear of supporting members of rotating elements increases noise and vibration. In addition, roadway roughness can cause a significant vibration, especially when driving at high speed;

• increased concentration of harmful substances in the air caused by the emission of exhaust fumes during engine operation. This hazard is also possible when repairing a truck mixer in a closed room (garage, hangar) with the running engine without ventilation. Increased dust concentration in the driver's cab caused by roadway dust, especially without hard surface, as well as in the area of the mixing drum feed inlet with dry fine concrete mixture components;

• hazard of an emergency on the road in case of failure of a unit or a part affecting traffic safety [3, 4];

• hazard of tipover (sliding) of a truck mixer when driving on soft grounds near pot holes, pits, when driving on slopes with an angle exceeding the permissible level;

• hazard of accidental ingress and subsequent winding of the operator's clothing on rotating structural elements.

Technical and technological solutions to reduce hazards.

For protection from the rotating elements, there are protective covers to prevent the possibility of winding of operator’s clothes. Noise insulation of the cabin with soundproof screens is used to protect a driver against noise. The noise coming from the mechanical drive of the mixing drum is eliminated using the design of the hydraulic drive.

The main element that protects the driver from vibration is his seat. A seat has special elements to perform these functions, (springs, insulating material, shock absorbers) designed to absorb vibration. To protect the car from vibrations caused by road surface irregularities, a suspension system including shock absorbers and springs is used. Vibration reduction from the rotating elements is achieved through timely maintenance services and repairs of the nodes, preventing them from excessive wear.

To protect against high concentrations of harmful substances (dust), the feed inlet has a protective cover. For protection against poisoning by exhaust fumes of a car it is forbidden to start the engine in closed rooms (hangars, garages) which are not equipped with ventilation. To improve air exchange there are hatches, ventilators in the driver's cab. To maintain the optimum temperature in the cabin a heating unit is used in winter and air conditioning in summer.

The reduction of driver fatigue is achieved by reducing levers and pedals force to regulatory limits: the steering wheel force is 20 N, the force on the levers is 20-60 N, the force on the pedals is 80-120 N.

Firefighting equipment on truck mixers are extinguishers. Kits are used as a means of first aid, the completeness of which is determined by regulatory documents.

To prevent an emergency on the road, truck mixers undergo technical inspection before leaving to determine the serviceability of the main car systems. To prevent injuries during the inspection and repair of concrete mixers with tipping cab, the latter is equipped with a locking mechanism to prevent its spontaneous lowering. Repair and maintenance of machines is carried out at specially equipped stations that meet safety requirements. Repair and adjustment work is carried out at the switched-off engine (except for separate types of adjustment works).

In order to prevent the truck mixer tipover, the driver is prohibited to move on the surface, the angle of inclination of which exceeds the limit values.

Methods for calculating the truck mixer stability. Under the machine stability, we understand its ability to move in various environments without tipping over and without lateral sliding of the wheels of all axles of the chassis or one of them. The stability of the truck mixer is checked for the most unfavorable case when the maximum volume of concrete mixture is prepared in accordance with the technical characteristics of the unit.

The preliminary analysis showed that the most dangerous is the machine transverse stability loss with its subsequent tipover or sliding. Lateral stability checking is the determination of the limit angle of the slopes α, at which the truck mixer can move without tipping over.

We assume that the concrete mixture is evenly distributed in the mixing drum, due to its rotation, as well as the presence of blades. The stability condition is an inequality of overturning and restoring moments, with respect to the tipping axis, this axis passes through the point A (Fig.1). The calculation method is given in table 1.

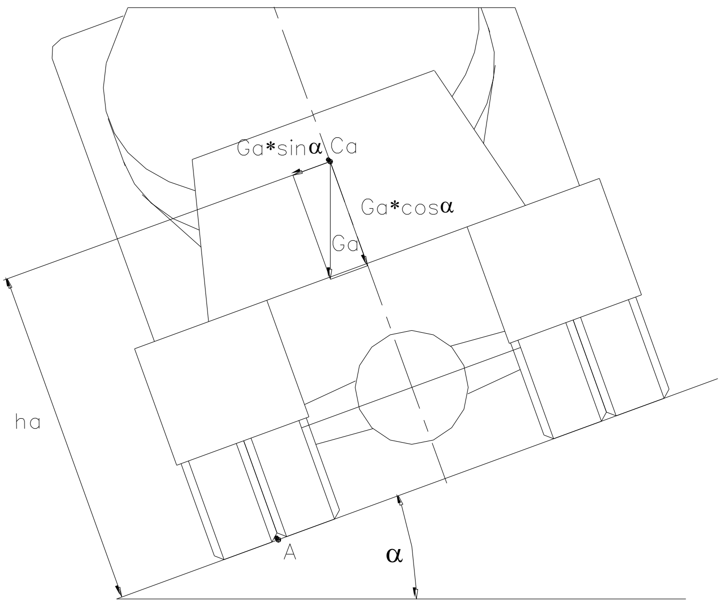


Fig.1. Scheme for calculation of lateral overturning stability

Table 1

Summary table of stability check of a truck mixer

Risk factor	Moment inequality	Tipping and sliding limit angles
Stability condition	$G_A \cdot h_A \cdot \sin\alpha \le G_A \cdot 0.5B \cdot \cos\alpha$	limit angle of transverse inclination: $\alpha = \arctan\frac{0.5B}{h_A} = \arctan\frac{0.5 \cdot 1.77}{1.58} = 31^0$
Slippage	$G_A \cdot \sin\alpha \le G_A \cdot \varphi_{СЦ}' \cdot \cos\alpha$	– for dry road surface: $\varphi_{СЦ}' = (0.6...1) \cdot 0.75 = 0.6$ – for wet road surface: $\varphi_{СЦ}' = (0.6...1) \cdot 0.5 = 0.4$
Sliding	$G_A \cdot \sin\alpha \le G_A \cdot \varphi_{СЦ}' \cdot \cos\alpha$	– for dry road surface: $\alpha = \arctan\varphi_{СЦ}' = \arctan 0.6 = 30^0$ – for wet road surface: $\alpha = \arctan\varphi_{СЦ}' = \arctan 0.4 = 22^0$

*G_A — weight of a truck mixer, including concrete mix

Conclusion. The analysis is conducted of the main potential hazards during the operation of a truck mixer, as well as the main technical and technological solutions to reduce hazards. The method for calculating the truck mixer stability is formulated, in which the limiting angles of tipover and sliding in the transverse plane for a stationary and moving machine are determined.

Implementation of the above-mentioned solutions and recommendations will improve the comfort of the operator and prevent possible negative consequences from the impact of harmful and dangerous production factors while working with the mixer truck.

References

1. Nadezhnost’ v tekhnike (SSNT). Terminy i opredeleniya: GOST 27.002-2015. Mezhgosudarstvennyy Sovet po standartizatsii, metrologii i sertifikatsii. [Reliability in technology (SAST). Terms and definitions: GOST 27.002–2015. Interstate Council for Standardization, Metrology and Certification.] Moscow: Standartinform, 2015, 23 p. (in Russian).

2. O promyshlennoy bezopasnosti opasnykh proizvodstvennykh ob’ektov: feder. zakon No. 116-FZ. Elektron. Fond pravovoy i normativ.-tekhn. dokumentatsii. Konsoetsium "Kodeks". [On industrial safety of hazardous production facilities: Federal law No. 116–FZ. Electron. fund of legal and norm.-tech. documentation. Consortium "Kodeks".] Available at: http://docs.cntd.ru/document/9046058/ (accessed 03.03.2017) (in Russian).

3. Teplyakova, S.V. Analiz printsipov obespecheniya absolutnoy bezotkaznosti detaley mashin. [Analysis of the principles of ensuring the absolute reliability of machines' parts.] Vestnik Donetskoy akademii avtomobil'nogo transporta, 2015, no. 1, pp. 65-70 (in Russian).

4. Kotesova, A.A. et al. Analiticheskoe opredelenie parametrov raspredeleniya veybulla dlya sovokupnosti konechnogo ob'ema po tverdosti stali. [Analytical determination of Weibull distribution parameters for population of final volume on steel hardness.] Novye tekhnologii, 2012, no. 4, pp. 56-61 (in Russian).

Received 05.05.2019
Submitted 06.05.2019
Scheduled in the issue 05.06.2019

Autors:

Teplyakova Svetlana Viktorovna,
assistant of the Department "Motor vehicles, construction and road facilities, Don State Technical University, (1, Gagarin sq., Rostov-on-Don, 344000, Russia), candidate of techn. sciences,
svet-tpl@yandex.ru

Kotesova Anastasiya Aleksandrovna,
associate professor of the Department "Motor vehicles, construction and road facilities", Don State Technical University, (1, Gagarin sq., Rostov-on-Don, 344000, Russia) candidate of techn. sciences,
a.kotesova@mail.ru

Nedoluzhko Aleksandr Ivanovich,
associate professor of the Department "Motor vehicles, construction and road facilities", Don State Technical University, (1, Gagarin sq., Rostov-on-Don, 344000, Russia) candidate of techn. sciences,
alexsander1948@yandex.ru

UDC 331.45
DOI 10.23947/2541-9129-2019-2-18-22

DIGITAL TECHNOLOGIES PROSPECTS IN PRODUCTION CONTROL OF ELEVATORS, FLOUR, CEREALS AND FEED PRODUCTION

Biryulin A. E.
Don state technical University, Rostov-on-Don, Russian Federation

my_vesto4ka@mail.ru

The reasons of overuse of production capacities at storage and processing of vegetable raw materials are determined. The growth rates of gross output of grain and leguminous crops are considered. Elevators, objects of flour, cereals and feed production are considered as important structural elements of micro and macroeconomics. The paper predicts the application of digital technologies in production control and online monitoring of dangerous and harmful production factors. Ways of implementation of this approach on real production processes, which are, controlled both by the operating organization and by the Supervisory authorities are considered. Accidents and fatal injuries at hazardous production facilities of storage and processing of plant raw materials are considered.

Keywords: production control, digital technology, risk-based approach, explosion, accident, fatal accident, hazardous production facilities, safety, human factor, production.

УДК 331.45
DOI 10.23947/2541-9129-2019-2-18-22

ПЕРСПЕКТИВЫ ПРИМЕНЕНИЯ ЦИФРОВЫХ ТЕХНОЛОГИЙ В ПРОИЗВОДСТВЕННОМ КОНТРОЛЕ ЭЛЕВАТОРОВ, МУКОМОЛЬНЫХ, КРУПЯНЫХ И КОМБИКОРМОВЫХ ПРОИЗВОДСТВ

Бирюлин А. Е.
Донской государственный технический университет, г. Ростов-на-Дону, Российская Федерация
my_vesto4ka@mail.ru

Определены причины перегрузки производственных мощностей при хранении и переработке растительного сырья. Рассмотрены темпы роста валового сбора урожая зерновых и зернобобовых культур. Элеваторы, объекты мукомольного, крупяного и комбикормового производства рассмотрены как важные структурные элементы микро- и макроэкономики. Спрогнозировано развитие цифровых технологий в производственном контроле и онлайн мониторинге опасных и вредных факторов. Определены методы реализации данного подхода на примере производственных процессов, контролируемых эксплуатирующей организацией и надзорными органами. Рассмотрены ситуации аварийности и смертельного травматизма на опасных производственных объектах хранения и переработки растительного сырья.

Ключевые слова: производственный контроль, цифровые технологи, риск-ориентированный подход, взрыв, авария, несчастный случай со смертельным исходом, опасные производсвтенные объекты, обеспечение безопасности, человеческий фактор, производство.

Introduction. Elevators, flour, cereals and feed production facilities are an important part of economic activity of many regions of the Russian Federation. These regions satisfy the needs of the state in certain types of plant raw materials, allow storing strategic reserves, creating stability in the market of food products. They provide feed to certain areas of livestock, as well as the sale of raw materials and products for export. At the same time, during the operation of hazardous production facilities for storage and processing of plant raw materials, there are certain problems associated with the risk of fire and industrial injuries with fatal outcome [1].

In accordance with the Federal law "On industrial safety of hazardous production facilities" No. 116-FZ of 21.07.1997 [2] these facilities are classified as hazardous production facilities (HPF) hazard class III (medium hazard). According to the accident analysis [3], from 2013 to 2017, 6 accidents and 21 fatal accidents occurred at the facilities of storage and processing of plant raw materials. 50% of accidents and 70% of fatal accident of the total number occurred at the facilities of hazard class III.

Main part. Recently, despite the increase in the gross yield of plant raw materials of grain and leguminous crops in the Russian Federation, the relative amount of storage and processing of such raw materials is reduced [3]. So, in 2017 134.1 million tons of processed cereals and legumes were harvested. At the same time, 14.9 million tons of harvested crop are accounted for 1,000 HPF for storage and processing of plant raw materials, which is 4.3 million tons more compared to 2013 [3]. Table 1 illustrates a stable increase in the specific number of units of plant raw materials per unit of storage and processing. This increase contribute to the requirements of the modern market, which sets certain criteria in production volumes, timing of sales, etc. The load on HPF for storage and processing of plant raw materials increases. This has a negative impact on the operation of these facilities and the organization of production control.

Table 1

Ratio of gross yield to the number of HPF for storage and processing of plant raw materials

No.	Indicators	Time period				
		2013	2014	2015	2016	2017
1	Number of organizations operating HPF for storage and processing of plant raw materials	4132	3750	3789	4621	4017
2	Number of HPF for storage and processing of plant raw materials	10579	9838	9448	9286	8961
3	Gross yield of grain and leguminous crops in the Russian Federation, mln t	91.3	110.8	104.3	119.1	134.1
4	Gross yield of grain and leguminous crops in the Russian Federation, per 1,000 of HPF for storage and processing of plant raw materials, mln t	8.6	11.2	11	12.8	14.9

From the obtained data [5] it follows that the unfavorable load on hazardous production facilities for storage and processing of plant raw materials is not due to the large amount of the harvested crop, but to the increase in the specific amount of harvested plant raw materials per unit of the object for its processing. For this period, most accidents occurred in the Republic of Tatarstan, the second place takes the Rostov region [3]. As table 2 shows, the load has increased over the entire analyzed period.

Table 2

Gross yield in agricultural regions, million tons

No.	Regions of the Russian Federation	2013	2014	2015	2016	2017
1	Republic of Tatarstan	2.6	3.36	3.4	4.3	5.01
2	Rostov region	6.7	9.5	9.8	11.7	13.5
3	Krasnodar Krai	12.03	12.87	13.9	14.3	14.3

The increase in the load on HPF has the corresponding consequences, which are reflected in the deviation from the safety requirements, the established technological regulations, the deviation from the performance characteristics of the technological equipment established in the passport data and, importantly, in the increase in labor of workers operating and servicing these facilities.

As it was mentioned earlier, storage and processing facilities for plant raw materials are important economic agents, whose destabilization can significantly undermine the economic stability not only of a company's owner, but also of the entire region (Fig.1, 2). The main safety problems today are not so much technical as organizational problems, which determines the human factor as one of the leading causes of accidents [6].

Fig. 1. Explosion of dust-air mixture in elevator grain storage sections

Fig. 2. Fire of one of the elevator grain storage sections

Today, the question of the degree of safety in production of is raised. The current level of technology allows changing the emphasis of production from increasing productivity to improving the feasibility and safety [7]. In order to produce safer and more socially justified, it is necessary to integrate modern technological solutions with the existing practices and established requirements in industrial safety. It is expressed in the Decree of the President of the Russian Federation of 06.05.2018 No. 198 "On the fundamentals of the Russian Federation state policy in the field of industrial safety up to 2025 and beyond" [8].

The implementation of such ideas is possible with the help of remote monitoring in production control from the position of digital technologies in a risk-based approach. Remote monitoring should be used for all technological operations associated with the operation of a hazardous production facility. These operations are acceptance of plant raw materials, cleaning, drying, production, transportation, storage of plant raw materials and products, as well as shipment of products. All of these technological operations should be controlled in real time, both by man and by monitoring systems, which allows realization of the existing level of digital technologies development. At this level of control, the information will be analyzed in real time. This will enable organizations operating hazardous production facilities to have advantages in data processing and decision-making speed. A certain prospect opens up for supervisory authorities, which will be able to access the information of the supervised objects remotely, without the in-

spector going to the objects under their supervision. In the future, it should be a dynamic system of continuous monitoring, which will continuously provide information to owners, supervisory authorities and the public on the levels of danger of the production facility at any given time. [10]. The related works should also controlled, such as ensuring cleanliness in buildings and structures of the facility, cleaning of bunkers and silos, work at height, fire works and other works of increased danger.

Conclusion. Production control should not be aimed at the fulfillment or non-fulfillment of certain safety requirements and related consequences, as this creates a large information "gap" between the events and the consequence. A static system cannot respond quickly to changes in technological operations, human errors or failures in the operation of technological equipment. The main goals that should be pursued in the modernization of production control methods are dynamism, speed of reaction to changes in the production environment and the ability to adapt to all technological operations and existing types of work at the facilities. It is these qualities that can significantly reduce the list of existing problems in ensuring production control and bring the concept of safety to a completely new qualitative level.

References

1. Egorova, I.V., Zholobova, M.V., Korsunova, D.A. Analiz avariy na mukomol'nom proizvodstve i razrabotka meropriyatiy po vzryvopreduprezhdeniyu. [Analysis of accidents in the milling industry and development of measures for explosion prevention.] Obrazovanie, nauka, proizvodstvo: sb. trudov VIII mezhdunar. molodezhn. foruma [Education, science, production VIII international youth forum] 2016, pp. 152-156 (in Russian).

2. O promyshlennoy bezopasnosti opasnyh proizvodstvennyh ob'ektov: feder. zakon No.116-FZ ot 21.07.1997: [On industrial safety of the Russian Federation. Federal law no. 116-FZ of 21 July 1997.] Available at: http://www.consultant.ru/document/cons_doc_LAW_15234/ (accessed 09.01.2019) (in Russian).

3. Ezhegodnye otchety o deyatel'nosti Federal'noy sluzhby po ekologicheskomu, tekhnologicheskomu i atomnomu nadzoru. Rostekhnadzor. [Annual reports on the activities of the Federal service for environmental, technological and nuclear supervision. Rostekhnadzor.] Available at: http://www.gosnadzor.ru/public/annual_reports/ (accessed: 09.01.2019) (in Russian).

4. Ezhemesyachnyy obzor situatsii v agropromyshlennom komplekse. Ministerstvo sel'skogo khozyaystva Rossiyskoy Federatsii. [Monthly review of the situation in the agro-industrial complex. Ministry of agriculture of the Russian Federation.] Available at: http://mcx.ru/analytics/apk-review/ (accessed: 09.04.2019) (in Russian).

5. Sel'skoe hozyaystvo i APK [Agriculture and agribusiness] Official portal of the Government of the Rostov region. Available at: http://old.donland.ru/Donland/Pages/View.aspx?pageid=124053&mid=128713&itemId=127009. (accessed: 09.04.2019) (in Russian).

6. Kotelnikov, V.V., Egelskaya, E.V., Korotkiy, A.A. Risk-orientirovannyj podhod k attestatsii spetsialistov v organizatsiyah, ekspluatiruyushchikh opasnye proizvodstvennye ob'ekty. [Risk-oriented approach to certification of specialists in organizations operating hazardous production facilities] Nauchno-tekhnicheskiy vestnik Bryanskogo gosudarstvennogo universiteta. 2018, no. 3, pp. 291-302 (in Russian).

7. Bykov A.A. O problemakh tekhnogennogo riska, bezopasnosti tekhnosfery i tekhnologicheskom budushchem: vzglyady, idei i mysli akademika V.A. Legasova. [On the problems of industrial risk, safety of the technosphere and technological future: views, ideas and thoughts of the academician V. A. Legasov.] Strategiya grazhdanskoy zashchity: problemy i issledovaniya, 2011, vol. 1, no. 1(1) (in Russian).

8. Ob osnovakh gosudarstvennoy politiki Rossiyskoy Federatsii v oblasti promyshlennoy bezopasnosti na period do 2025g. i dal'neyshuyu perspektivu: Ukaz Prezidenta RF ot 06.05.2018g. No.198

[On the basics of state policy of the Russian Federation in the field of industrial safety for the period up to 2025 and beyond. Decree of the President of the Russian Federation of 06.05.2018 No.198] Available at: http://kremlin.ru/acts/bank/43022. (accessed: 09.01.2019) (in Russian).

9. Korotkiy, A.A. et al. Sovershenstvovanie sovremennyh sistem bezopasnosti bashennyh kranov na osnvoe tsifrovykh tekhnologiy v usloviyah risk-orientirovannogo nadzora. [Improvement of modern security systems of tower cranes based on digital technologies in the conditions of risk-oriented supervision.] Science and business: development ways, 2018, no 7(85), pp. 46-54 (in Russian).

Received 05.03.2019
Submitted 06.03.2019
Scheduled in the issue 15.02.2019

Autor:

Biryulin Aleksandr Evgenyevich,
post-graduate student, Don State Technical University, (1, Gagarin sq., Rostov-on-Don, 344000, Russia),
my_vesto4ka@mail.ru

UDC 62-78(075)
DOI 10.23947/2541-9129-2019-2-23-32

ENGINEERING RISK ASSESSMENT OF ELECTROMAGNETIC SITUATION IN THE AREA OF ROSTOV-ON-DON TELEVISION CENTER

Kuhta A. I., Mamatchenko N. S.
Don state technical University, Rostov-on-Don, Russian Federation

alexey-semenov82@mail.ru

The electromagnetic field (EMF) poses a serious threat to human life and health. The biological effect of EMF exposure in a long-term exposure accumulates. The result of this may be degenerative diseases of the central nervous system, blood cancer (leukemia), brain tumors, hormonal diseases, and malfunctions of certain organs and the human body as a whole. The purpose of the work is a theoretical assessment of the danger of electromagnetic situation in the area of Rostov-on-Don television center. The task is to determine the dangerous and harmful zone for the population due to the electromagnetic impact of the television center. The authors plan to: find the electric field strength taking into account the television center power transmitters, antenna amplification and the distance to residential facilities; determine radiant exposure at different distances from the television center; compare the results with the MPL of EMF radiant exposure taking into account sanitary and epidemiological requirements; find ways to protect residents from EMF effects. The result of the research is the theoretical assessment of the electromagnetic situation near the station. The dangerous and harmful zone for the population and the compliance with the sanitary norms and rules of placement of radio-television and radar stations №1823-78 are determined. The objects of the Zheleznodorozhny

УДК 62-78(075)
DOI 10.23947/2541-9129-2019-2-23-32

ИНЖЕНЕРНАЯ ОЦЕНКА ОПАСНОСТИ ЭЛЕКТРОМАГНИТНОЙ ОБСТАНОВКИ В РАЙОНЕ ТЕЛЕЦЕНТРА ГОРОДА РОСТОВ-НА-ДОНУ

Кухта А. И., Маматченко Н.С.
Донской государственный технический университет, г. Ростов-на-Дону, Российская Федерация
alexey-semenov82@mail.ru

Электромагнитное поле (ЭМП) представляет серьезную опасность жизни и здоровью человека. Биологический эффект от воздействия ЭМП в условиях длительного многолетнего воздействия накапливается, в результате возможны дегенеративные заболевания центральной нервной системы, рак крови (лейкозы), опухоли мозга, гормональные заболевания, нарушения нормального функционирования как отдельных органов, так и организма человека в целом. Целью настоящей работы является теоретическая оценка опасности электромагнитной обстановки в районе телецентра города Ростов-на-Дону. Задача работы состоит в определении опасной и вредной для проживания населения зоны, возникшей в результате электромагнитного воздействия телецентра. Авторы планируют: найти напряженности электрического поля с учетом мощностей передатчиков телецентра, усилений антенн и расстояния до жилых объектов; определить энергетические экспозиции на различных расстояниях от телецентра; сравнить полученные результаты с предельно допустимым уровнем (ПДУ) энергетических экспозиций ЭМП с учетом санитарно-эпидемиологические требований; определить способы защиты жителей района от воздействий ЭМП. В результате выполненной работы: проведена теоретическая оценка электромагнитной обстановки в районе расположения станции; определена опасная и вредная зона для проживания населения; выяснено соответствие радиотелевизионных и радиолокационных станций №1823-78 санитарным нормам и

district of Rostov-on-Don the inhabitants of which are exposed to electromagnetic waves are specified. Ways of protection of inhabitants from EMF are found.

Keywords: electromagnetic field, electromagnetic impact, electromagnetic environment, TV center, electric field strength, magnetic field strength, radiant exposure.

правилам размещения; указаны объекты Железнодорожного района г. Ростов-на-Дону, жители которых подвергаются облучению электромагнитными волнами; определены способы защиты жителей района от ЭМП.

Ключевые слова: электромагнитное поле, электромагнитное воздействие, электромагнитная обстановка, телевизионный передающий центр, напряженность электрического поля, напряженность магнитного поля, энергетическая экспозиция.

Introduction. Electromagnetic field (EMF) has a negative impact on human health. Factors affecting the development of pathological reactions of the organism under the influence of EMF are:

• electric and magnetic field strength;
• duration of the electromagnetic impact;
• person's age and state of health;
• air humidity;
• irradiation area (arms, legs, head, etc.));
• frequency and modulation of electromagnetic radiation.

Exposure to EMF leads to the appearance of ionic currents that flow only through the intercellular fluid, since the cell membranes are dielectrics.

Main part. Thermal and non-thermal effects characterize the biological effect of EMF in the radio frequency range. Thermal effect means an integral increase in body temperature or its individual parts under general or local irradiation. Non-thermal effect is associated with the transition of electromagnetic energy in the human body into a non-thermal form of energy in the form of a molecular resonance process, photochemical reaction, etc. Due to the fact that the biophysical properties of body tissues are heterogeneous, the absorption of heat energy causes uneven heating at the interface of tissues with high and low water content, which determines the respectively high and low absorption coefficient.

EMF most intensively affect organs with a high water content. Overheating is especially harmful for tissues with poorly developed vascular system or with insufficient blood circulation (kidneys, brain), since the circulatory system can be regarded as a water cooling system. Eye irradiation causes clouding of the lens, which manifests itself quickly enough (a few days or weeks after irradiation). Intensive electromagnetic field of industrial frequency causes malfunction of the central nervous and cardiovascular systems. In this case, there is an increased fatigue, reduced precision in movement, changes in blood pressure and pulse, heart pain, accompanied by palpitation and arrhythmia. Special attention should be paid to the assessment of individual consequences of long-term contact of the population with EMF: the development of cancer (including leukemia), diseases associated primarily with the degradation of nerve cells.

The earliest clinical evidence of the effects of electromagnetic radiation on humans is nervous system functional disorders in the form of autonomic dysfunction of neurasthenic and asthenic syndrome. Persons who have been in the area of exposure to EMF for a long time, note weakness, irritability, fatigue, memory impairment, sleep disturbance. Often these symptoms come with vegetative functions disorders. Cardiovascular system disorders are, as a rule, in the form of cardiophyshoneurosis: lability of pulse and blood pressure, tendency to hypotension, heart pains.

High-frequency electromagnetic radiation ionizes atoms or molecules in somatic cells and thereby disrupt the processes occurring in them. Electromagnetic oscillations heating cells, put molecules in ther-

mal motion, which leads to insufficient flow of substances through membrane, and consequently, to metabolic disorders. The most sensitive to the action of electromagnetic fields are the neuroendocrinal and central nervous systems. In the latter case, there are subjective perceptions in the form of the increased fatigue and headaches. Neuroendocrinal regulation disorder affects the cardiovascular system, blood system, immunity, metabolism, reproductive function. There may also be changes in the heart rate and vascular reactions.

The literature describes changes in hematopoiesis, endocrine system, metabolic processes, and visual organs diseases. In the latter case, the thermal effect of radio-frequency radiation and microwaves leads to heating of the lens to the temperature exceeding the physiological norm, which causes the development of cataracts. This is one of the specific lesions of the electromagnetic field in the frequency range from 1.5 to 10 GHz. High-frequency electromagnetic waves also affect biological processes, breaking hydrogen bonds, which leads to the reorientation of DNA and RNA macromolecules [1].

Television transmitting center (television center) of Rostov-on-Don is a complex of technical means, providing television signals broadcast on the territory of the Rostov region, with the radius of reliable reception of about 80 km. Rostov television center is typical broadcast tower of project 3803 KM, located in Zheleznodorozhny district of Rostov-on-Don on Barrikadnaya street. The TV tower is the tallest building in the city. Its height is 195 meters. The existing network of transmitting devices of the regional radio-television transmitting center consists of six powerful and thirty-eight low-power stations. The power of television transmitters ranges from 0.01 to 50 kW.

The aim of the work is a theoretical assessment of the electromagnetic situation near Rostov-on-Don television center, followed by the vertex outcome realization on the basis of the parametric criterion "impact is greater than susceptibility", taking into account the classification of working conditions.

The object of the research — the television center of Rostov-on-Don.

The subject of the research is the electromagnetic field of the Rostov-on-Don television center.

Research problems:

1. to find the intensity of the electric field, taking into account the power of the transmitters of the television center, amplification of antennas and the distance to residential facilities;

2. to determine radiant exposures at different distances from the television center;

3. to compare the obtained results with the maximum permissible level (MPL) of EMF radiant exposures taking into account sanitary and epidemiological requirements;

4. to establish the measures of certainty of the vertex outcome on the basis of the parametric criterion "impact is greater than susceptibility".

At the first stage, we find the values of the intensity and density of the EMF energy flow when exposed to radiation on a nearby residential object, which is a residential nine-storey house located on 1st Barrikadnaya street at a distance of 80 m from the television center. We estimate the electromagnetic impact on the areas of 80 m and 300 m from the television center.

The electric field strength E, V/m, in the far zone of the antenna is associated with the transmitter power, antenna amplification and the distance from the antenna [2, 3]:

$$E = \frac{1}{D}(\sqrt{30 * P * Ga}),$$

where P — the input power of the antenna, W; Ga — the degree of antenna amplification in power in a given direction, which is determined from the antenna radiation pattern.

Next, we find the radiant exposure in the frequency range 30 kHz–300 MHz according to the formulas [4]:

$$ЭЭ_E = E^2 * T, \text{ (В/м)}^2\text{·ч};$$

$$ЭЭ_H = H^2 * T \text{, (А/м)}^2\cdot\text{ч,}$$

where H — the magnetic field strength, A/m; T — the time of exposure per shift, h.

Calculation of radiant exposure $ЭЭ_E$ is carried out at distances of 80 and 300 m from the radiation source. Here T = 24 h, since the impact of the electromagnetic field is around the clock.

Next, we find the energy flux density *ППЭ*, W/m, and the radiant exposure *ЭЭППЭ*, (μW /cm²)·h, in the frequency range of 300 MHz–300 GHz according to the formulas [6]:

$$ППЭ = \frac{P_{вых}}{4 * \pi * r^2};$$

$$ЭЭППЭ = ППЭ * T.$$

Fig. 1 presents the scheme of electromagnetic radiation effect in the frequency range of 470-862 MHz on a house located at a distance of about 80 m from the antennas to calculate the *ППЭ* parameter.

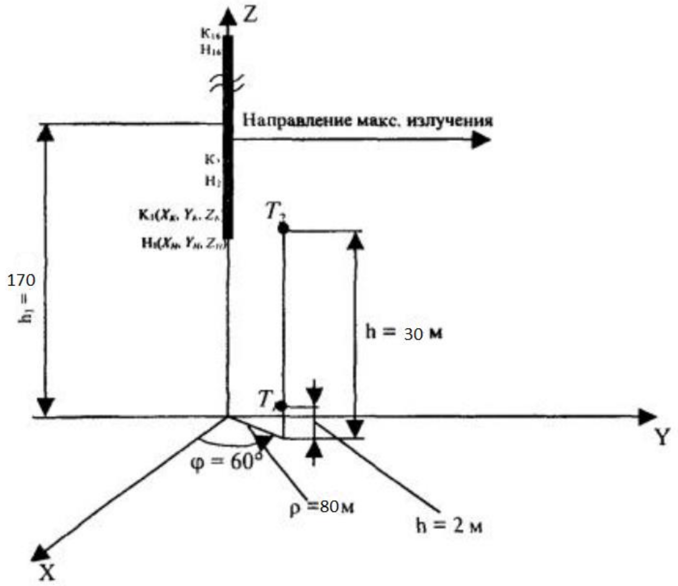


Fig. 1. Scheme of electromagnetic radiation effect of the antenna on a house located at a distance of about 80 m

The calculation of the *ЭЭППЭ* parameter is made taking into account the electromagnetic effect on the first and the ninth floors of a nine-storey building. During the calculation, we take into account the antennas height.

We use the following technical characteristics of the antennas in the calculations:

1. for corner antennas operating frequency ranges: 66-74 MHz, 87.5–108 MHz; maximum input power — 10 kW;

2. for vibrator 4-storey broadband antennas operating frequency ranges: 66-74 MHz, 87.5 -108 MHz; maximum input power — 5 kW;

3. for four-storey panel antennas "Sivash-Skuy" series operating frequency range: 470-862 MHz; height — 4.2 m; maximum input power — 32 kW;

4. for two-storey antennas "LPA-G" operating frequency ranges: 66-74 MHz, 87.5–108 MHz, maximum input power — 20 kW;

5. for wideband eight-storey panel antennas "SIVASH-2TS" series operating frequency range: 470-860 MHz, input power up to 40 kW.

Table 1 presents the calculation results for the television center of Rostov-on-Don.

Table 1

Values of parameters of electromagnetic influence of the television center

No.	Antenna type, control conditions	Electric field intensity *E*, V/m, at a distance to the place of control		Radiant exposure at a distance to the place of control	
		80 m	300 m	80 m	300 m
1.	Corner antennas	12.89	3.4	ЭЭ=3987 (V/m)·h	ЭЭ=277.4 (V/m)·h
2.	Vibrator 4-storey broadband antennas	12.16	3.24	ЭЭ=3548.77 (V/m)·h	ЭЭ=251.94 (V/m)·h
3.	Four-storey panel antennas "Sivash-Skyu" series At the level of the 1st floor of a nine-storey building	–	–	$ЭЭ_{ппэ}$=2544 μW /cm²·h	–
	Four-storey panel antennas "Sivash-Skyu" series At the level of the 9th floor of a nine-storey building	–	–	$ЭЭ_{ппэ}$=3352.8 μW /cm²·h	–
4.	Two-storey "LPA-G" antennas	13.67	3.65	ЭЭ=4484.85 (V/m)·h	ЭЭ=319.7 (V/m)·h
5.	Broadband eight-storey panel antennas "SIVASH-2TS" series At the level of the 1st floor of a nine-storey building	–	–	$ЭЭ_{ппэ}$=3504 μW /cm²·h	–
	Broadband eight-storey panel antennas "SIVASH-2TS" series At the level of the 9th floor of a nine-storey building	–	–	$ЭЭ_{ппэ}$=4672.8 μW /cm²·h	–

At the second stage of problems solving, the radiant exposure on the magnetic component is not considered, due to the fact that the maximum permissible levels for the frequency range 50 MHz–300 GHz are not established according to Sanitary Regulations and Norms SanPiN 2.2.4.3359–16 "Sanitary and epidemiological requirements for physical factors in the workplace" of June 21, 2016 No. 81.

In step 3, measures of certainty of the vertex outcome are established on the basis of the parametric criterion "impact is greater than susceptibility". The vertex outcome realization is measured at the condition of parameter overriding, or the magnitude of the impact *s* on the susceptibility *r*: $(s \geq r)$. "The probability of the condition realization $(s \geq r)$ is found by construction of a probabilistic parametric model "impact *s* — susceptibility *r*" using a model where the impact is greater than the susceptibility" [5].

We construct a probabilistic parametric model "impact *s* — susceptibility *r*" (Fig. 2). At the same time, the parameters m_r, m_s, σ_r, σ_s were selected in accordance with the classification of working conditions for the vertex outcome calculation [3].

For feature selection of m_r and σ_r of the susceptibility parameter, we use SanPiN 2.2.4.3359–16. Moreover, the values of MPL are determined taking into account the time of the impact of the factor during the working day in accordance with SanPiN 2.2.4.1191–03.

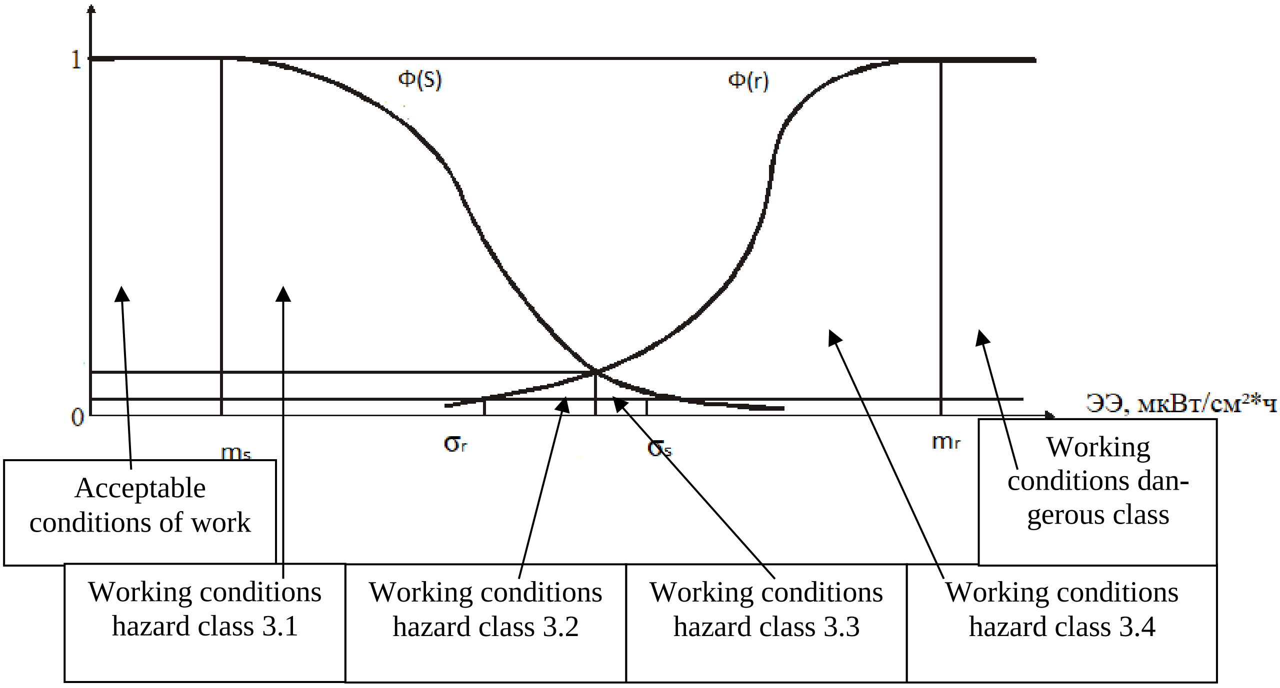


Fig. 2. Parametric models of impact and susceptibility taking into account the special assessment of working conditions

Further, taking into account the impact characteristics m_s and σ_s of radiant exposure of electromagnetic radiation, we determine the class of working conditions as follows.

In accordance with Federal law No. 426 of 28.12.2013 "On special assessment of working conditions", article 14 (classification of working conditions), we assign the values of the parametric model of impact and susceptibility:

ms — class 2 (acceptable conditions of work);

σr — subclass 3.1 (harmful working conditions of the 1st degree);

σs — subclass 3.3 (harmful working conditions of the 3rd degree);

mr — class 4 (hazardous working conditions).

At the fourth stage of problems solving we find the vertex outcome probability (threat to the lives of residents of the area) under the influence of radiation on a nearby residential facility. The residential 9-storey building (1st Barrikadnaya street) is located at a distance of 80 m from the radiation source. Based on the calculated data, probabilistic parametric models "impact s — susceptibility r" were constructed: model ($s \geq r$) at a distance of 80 m (Fig. 3); model ($s \leq r$) at a distance of 300 m (Fig. 4).

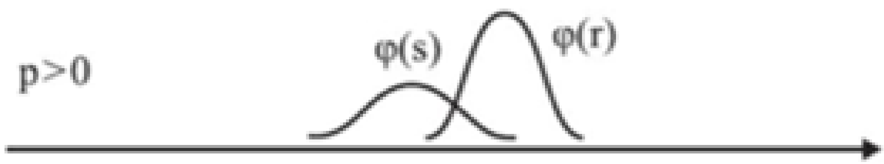


Fig. 3. Parametric model "impact s — susceptibility r" taking into account the distance of 80 m ($s \geq r$)

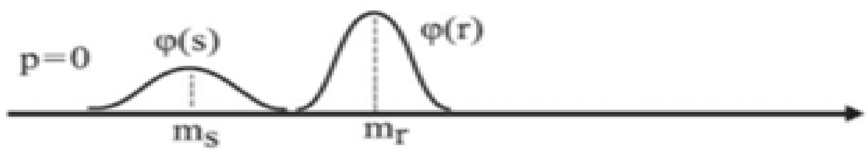


Fig. 4. Parametric model "impact s — susceptibility r" taking into account the distance of 300 m ($s \le r$)

Based on figures 3 and 4 of the parametric model, we determine the probability of exceeding the impact *s* over the susceptibility *r*: *Pro* ($s \ge r$) and the probability that the impact *s* is less than the susceptibility *r*: *Pro* ($s \le r$) [7].

For the case when the mathematical expectation of random impact is less than the mathematical expectation of random susceptibility, the probability that the action *s* is less than the susceptibility *r*: *Pro* ($s \le r$) is determined by the formula:

$$p1(u) = \Pr o(z \ge 0) = 0,5 - \Phi\left[\frac{mr - ms}{0,5(\sigma^2 r + \sigma^2 s)}\right] = 0,5 - \Phi(u).$$

In this expression, the parameter is a probabilistic "reduced parametric safety margin" (RPSM), expressed by the ratio of the difference between the mathematical expectations of the impact and the susceptibility to their total standard deviation [5]:

$$u = \frac{mr - ms}{0,5(\sigma^2 r + \sigma^2 s)}.$$

For the case when the mathematical expectation of random impact is greater than the mathematical expectation of random susceptibility, the probability of exceeding the impact *s* over the susceptibility *r*: *Pro* ($s \ge r$) is determined by the formula:

$$p2(u) = \Pr o(z \ge 0) = 0,5 + \Phi\left[\frac{ms - mr}{0,5(\sigma^2 r + \sigma^2 s)}\right] = 0,5 + \Phi(u).$$

Replacing the "less" condition with the "more" condition in the above expressions is accompanied by replacing the plus sign with a minus sign:

$$\frac{ms - mr}{0,5(\sigma^2 r + \sigma^2 s)} = -\frac{mr - ms}{0,5(\sigma^2 r + \sigma^2 s)} = -u.$$

It is obvious that if the positive value (+*u*) is a characteristic of the "safety margin", then the negative value (–*u*) expresses the presence and increase of "danger" with a further increase in the magnitude of the impact [6].

To find the probabilities $p1(u)$ and $p2(u)$, we use the Laplace function $\Phi(u)$.

To find the probabilities p1(u) and p2(u), we use the Laplace function f(u).

The electromagnetic situation danger in the area of Rostov-on-Don television center. Tables 2-6 provide the calculation results of the probability values of realization of the vertex outcome Pro ($s \ge r$) in the function of the given parametric safety margin *u* for two variants of the ratios of mathematical expectations of impact and susceptibility (1): $(mr \ge ms)$ and (2): $(ms \ge mr)$.

Table 2

Energy characteristics of corner antennas
with frequency ranges: 66–74 MHz and 87.5–108 MHz

EE μW /cm²·h	u	$\Phi(u)$	$p1(u)\|(mr \geq ms)$	$p2(u)\|(ms \geq mr)$
277.4	0.9896	0.33646	0.83646	0.16354
3987	1.037	0.35083	0.15	0.85

Table 3

Energy characteristics of vibratory 4-storey broadband antennas with frequency ranges: 66-74 MHz and 87.5–108 MHz

EE μW /cm²·h	u	$\Phi(u)$	$p1(u)\|(mr \geq ms)$	$p2(u)\|(ms \geq mr)$
3548.77	1.031	0.34849	0.15151	0.84849
251.94	0.989	0.336	0.836	0.164

Table 4

Energy characteristics of four-storey panel antennas
with frequency range 470-862 MHz

EE μW /cm²·h	u	$\Phi(u)$	$p1(u)\|(mr \geq ms)$	$p2(u)\|(ms \geq mr)$
2544	1.126	0.369	0.131	0.869
3352.8	1.179	0.38	0.12	0.88

Table 5

Energy characteristics of two-storey LPA-G antennas
with frequency ranges: 66-74 MHz and 87.5–108 MHz

EE μW /cm²·h	u	$\Phi(u)$	$p1(u)\|(mr \geq ms)$	$p2(u)\|(ms \geq mr)$
4484.85	1.0436	0.35	0.15	0.85
319.7	0.99	0.33891	0.839	0.161

Table 6

Energy characteristics of broadband eight-storey panel antennas
with frequency range 470-860 MHz

EE μW /cm²·h	u	$\Phi(u)$	$p1(u)\|(mr \geq ms)$	$p2(u)\|(ms \geq mr)$
3504	1.189	0.382	0.118	0.882
4672.8	1.278	0.398	0.102	0.898

The tables present the energy characteristics of the antennas of Rostov-on-Don television center and the probability of vertex outcomes realization taking into account the distance from the source of electromagnetic radiation.

Conclusion. The algorithm for calculation of probability of electromagnetic influence outcome realization on personnel in their labor activity is developed and approved. The scientific novelty of the

method is in finding the probability of occupational disease based on the parametric criterion of "impact is greater than susceptibility", taking into account the classification of working conditions.

The algorithm allows us to calculate quantitative measures of occupational diseases assessment in accordance with the requirements of *OHSAS* 18001:2007 "Order of occupational safety and health assessment". A parametric model "impact of electromagnetic fields of different frequency ranges — susceptibility" was built and probabilities of occurrence of diseases were estimated on the example of the system "television center— the inhabitants of a residential nine-storey building on 1-st Barrikadnaya st. of Rostov-on-Don". At the same time, it is proved that the residents living in this house are exposed to electromagnetic influence, which corresponds to the harmful class of working conditions 3.4. With a probability of 0.9 (for nine out of ten people), there is a threat of the emergence and development of severe forms of diseases. Working personnel of the television center using PPE are exposed to electromagnetic influence, which corresponds to the harmful class of working conditions 3.3. With a probability of 0.9 (for nine out of ten employees of the television center), there is a threat of the emergence and development of occupational diseases of moderate severity. It is concluded that it is necessary to apply organizational and technical measures to reduce the radiation power. These theoretical calculations require confirmation in practice by measurements.

References

1. Gichev, Yu.P., Gichev Yu.Yu. Analiticheskiy obzor. Vliyanie elekteomagnitnykh poley na zdorov’e cheloveka. [Analytical review. Influence of electromagnetic fields on human health.] Novosibirsk: izdatel’stvo RAN, Sibirskoe otdelenie gosudarstvennoy publichnoy nauchno-tekhnicheskoy biblioteki, 1999, pp. 39-44 (in Russian).

2. Dyakov, A.F. et al. Elektromagnitnaya sovmestimost’ v elekroenergetike i elektrotekhnike. [Electromagnetic compatibility in power engineering and electrical engineering.] Moscow: Energoatomizdat, 2008, 768 p. (in Russian).

3. Sanitarnye normy i pravila razmeshcheniya radiotelevizionnykh i radiolokatsionnykh stantsiy: SanPiN 1823-78. [Sanitary Rules and Regulations of placement of broadcasting and radiolocation stations: SanPiN 1823-78.] Electronnyy fond pravovoy i notmativ.-tekhn dokumentatsii. Kosortsium "Kodeks". [Electron. fund of legal and norm.-tech. documentation. Consortium "Kodeks".] Available at: http://docs.cntd.ru/document/471810978 (accessed 02.02.2019) (in Russian).

4. Sanitarno-epidemiologicheskie trebovaniya k fizicheskim faktoram na rabochikh mestakh: SanPiN 2.2.4.3359–16. [Sanitary and epidemiological requirements for physical factors in working places: SanPiN 2.2.4.3359–16.] Electronnyy fond pravovoy i notmativ.-tekhn dokumentatsii. Kosortsium "Kodeks". [Electron. fund of legal and norm.-tech. documentation. Consortium "Kodeks".] Available at: http://docs.cntd.ru/document/420362948 (accessed 02.02.2019) (in Russian).

5. Esipov, Yu.V., Samsonov, F.A., Cheremisin, A.I. Monitoring i otsenka riska system zashchita – ob’ekt – sreda. [Monitoring and risk assessment of protection — object — environment systems.] Moscow: Izdatel’stvo LKI, URSS, 2011, pp. 92-100 (in Russian).

6. Esipov, Yu.V., Dzhilyadzhi, M.S., Mamatchenko, N.S. Razrabotka algoritma rascheta veroyatnostnogo pokazatelya bezopasnosti tekhnicheskoy sistemy "zashchita – ob’ekt - sreda". [Development of calculation algorithm of the probability safety index of the technical system "protection - object - environment".] Safety of Technogenic and Natural Systems, Rostov-on-Don, Don State Technical University, 2017, pp. 75-86 (in Russian).

Received 01.11.2018
Submitted 01.11.2018
Scheduled in the issue 15.01.2019

Autors:

Kuhta Aleksey Igorevich,
master student, Don State Technical University, (1, Gagarin sq., Rostov-on-Don, 344000, Russia),
alexey-semenov82@mail.ru

Mamatchenko Nikolay Sergeevich,
post-graduate student, Don State Technical University, (1, Gagarin sq., Rostov-on-Don, 344000, Russia),
voleyboll.94@mail.ru

UDC 621.86
DOI 10.23947/2541-9129-2019-2-33-36

IMPROVING SAFETY OF EQUIPMENT BY RELIABILITY PROVISION

Zaytseva M.M., Megera G.I., Kopylov F.S., Krymskiy V.S.
Don state technical University, Rostov-on-Don, Russian Federation

alexey-semenov82@mail.ru

The issues of ensuring the reliability of equipment in order to improve the safety of its work are considered. The article proposes a method for modeling a general population of a finite volume using small samples of input data. The optimization of truck maintenance intervals is provided.

Keywords: safety, reliability, equipment failure, cost minimization, strength, loading, resource.

УДК 621.86
DOI 10.23947/2541-9129-2019-2-33-36

ПОВЫШЕНИЕ БЕЗОПАСНОСТИ РАБОТЫ ТЕХНИКИ ПУТЕМ ОБЕСПЕЧЕНИЯ ЕЕ НАДЕЖНОСТИ

Зайцева М. М. , Мегера Г. И. , Копылов Ф. С. , Крымский В. С.
Донской государственный технический университет, г. Ростов-на-Дону, Российская Федерация

marincha1@rambler. ru

Рассматриваются вопросы обеспечения надежности техники в целях повышения безопасности ее работы. В работе предлагается метод моделирования генеральной совокупности конечного объема с применением малых выборок исходных данных. Проведена оптимизация периодичности технического обслуживания грузового автомобиля.

Ключевые слова: безопасность, надежность, отказ техники, минимизация затрат, прочность, нагруженность, ресурс.

Introduction. To ensure equipment safety in such industries as construction, transport, engineering, there is the need to justify the indicators and reliability criteria that reflect the properties of the created technical systems. Safety requirements are functionally related to reliability requirements. The actual tasks of the industry in modern conditions are improving the safety of work, equipment reliability, labor costs and operating costs minimization.

Cost minimization. Technical failures and an insufficient level of reliability in general can lead to industrial injuries, increase in the cost of work, significant losses of time. In reliability calculation, it is necessary to apply the methods of reduction of labor, duration of tests and financial cost in obtaining the original data [1, 2]. The decrease in sample numbers in strength, loading and resource, as well as the use of indirect correlation methods for determining the strength of samples and parts lead to minimization of costs of production, operation and forecasting of the life of a part or vehicle as a whole (Fig. 1).

Reliability optimization. Reducing the samples volume in strength, loading and resource at the minimum error was carried out using the developed method to ensure the basic indicator of resource reliability. The method under consideration is based on the use of small samples of initial data and the distribution of absolute amplitudes for modeling the general population of a finite volume [3-5].

Distribution function of absolute amplitudes $W_{r_s} = x_r - x_s$. (r,s=1,...,n) has the form:

$$F(W)=\int_0^W f(W)dW,$$

where $f(W_{rs})$ is the density of amplitude distribution (in a general form):

$$f(W_{rs})=C_{rs}\int_{-\infty}^{+\infty} P^{r-1}(x)p(x)[P(x+W_{rs})-P(x)]^{s-r-1}p(x+W_{rs})\times[1-P(x+W_{rs})]^{n-s}dx,$$

$C_{rs}=\dfrac{n!}{(r-1)!(s-r-1)!(n-s)!}$; $P(x)$ — characteristic distribution function;

$p(x)$ is the characteristic probability density of the.

Ways to reduce the complexity, duration of testing and financial costs in obtaining the initial data for reliability calculations

Reduction of samples volume by strength, loading and resource by minimum error

Application of indirect correlation methods for determining the strength of samples and parts

Analytical justification of the reduction of sample volume and the transition to a finite volume set

The choice of indirect correlation method for determining the endurance limit of steel through hardness and tensile strength at the minimum error

Minimization of unit costs:
- cost of production and operation of parts;
- labour intensity,
- test duration

upon receipt of initial data

Fig. 1. Improving the efficiency of optimal reliability of equipment and its components

Fig. 2 shows the empirical and approximating distribution functions of the general population of the final resource volume of KAMAZ-4308 truck engine *Tp*. Optimization of the value of probability of no-failure operation (PNFO) of the car engine is carried out according to the criterion of optimization of the specific cost *Ci* (Fig. 3).

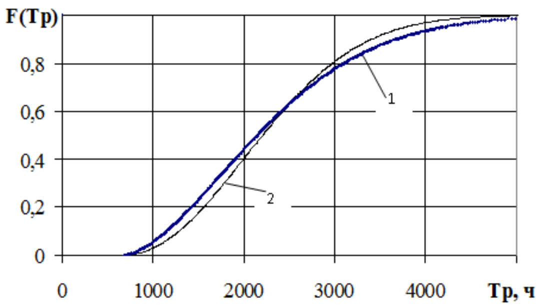


Fig. 2. Functions of distribution of GSKO resource of KAMAZ–4308 truck engine: 1 — empirical; 2 — approximating

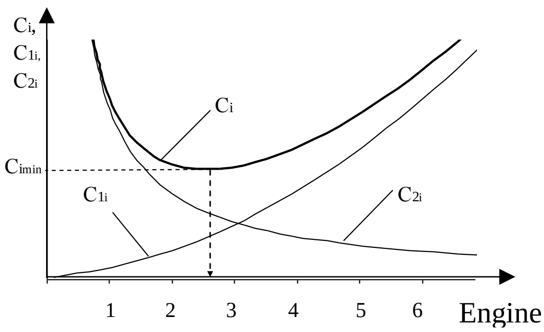


Fig. 3. Optimization of operation modes of the vehicle engine (and, accordingly, the probability of its no-failure operation)

It is necessary to calculate several *Ci* values for different modes of the car engine operation (use of different types of fuel; use of additives that increase the gasoline proknock properties; scheduled maintenance, etc.) and to determine the probability of no-failure operation $P(t)$. With the known functions $P(t)$ and failure rate $\lambda(t)$, it is possible to optimize the duration of the technical object operation in the periods between the scheduled maintenance. It is necessary to take into account the possibility of implicit failures.

Let us denote by u the additional financial losses where there is the agreement of other total expenses from implicit failures:

$$S(\tau)=Up(t<\tau)+Cp(t\geq\tau)+u\int_0^\tau tf(\tau-t)dt=U[1-P(\tau)]+CP(\tau)+u\int_0^\tau[1-P(t)]dt=$$

$$=U+(C-U)P(t)+u\left[\tau-\int_0^\tau P(t)dt\right].$$

Average unit cost over the time τ:

$$s(\tau)=\frac{1}{\tau}\left\{U+(C-U)P(t)+u\left[\tau-\int_0^\tau P(t)dt\right]\right\}.$$

Differentiating the expression by τ and equating the derivative to zero, we obtain the equation:

$$P(\tau)-\tau\frac{dP(t)}{dt}-\frac{u}{U-C}\left[\tau-\int_0^\tau P(t)dt\right]=\frac{U}{U-C}.$$

The desired solution of the equation is the optimal frequency of maintenance.

Let us imagine the risk function for a technical object with periodic maintenance in the form of:

$$S=CP_2(t)+UP_3(t).$$

Based on the minimization of the quantitative value of risk [6], we solve the problem of optimizing the value of the period between the planned maintenances. The value will have the size of the total unit costs associated with losses on the recovery and repair of equipment, as well as with the violation of the period of work due to machine complex downtime.

Obtaining practical results. The results of the optimization of the maintenance periodicity T_{opt} are summarized in table 1, where S_{min} is the smallest quantitative characteristic of risk; λ is the failure rate; τ is the time value of the period between maintenances; U/C is the ratio of costs in case of a sudden failure to the cost of maintenance. KAMAZ–4308 truck is selected as an example.

Table 1

The results of the problem solution of optimizing the duration of the period between the planned maintenances of KAMAZ–4308 truck

τ, h	U/C	Frequency of maintenance T_{opt}, h		
		$\lambda=10^{-8}\ h^{-1}$	$\lambda=10^{-7}\ h^{-1}$	$\lambda=10^{-6}\ h^{-1}$
10	10	9992	3154	992
	100	3152	990	307
	1000	990	306	91
	10000	306	91	23
20	10	14126	4456	1398
	100	4453	1395	428
	1000	1394	428	123
	10000	428	123	29
50	10	22321	7031	2196
	100	7022	2188	660
	1000	2187	659	179
	10000	659	179	37
100	10	31543	9920	3083
	100	9902	3066	907
	1000	3064	905	232
	10000	905	232	41

Thus, given $\lambda = 10^{-6}$ h^{-1} and $\tau = 100$ h, the cost ratio is U/C=100. Taking into account the final probabilities of states, the value of the minimum technogenic risk $S_{min} = 0.0613$ and the optimal periodicity of maintenance $T_{opt} = 907\text{h} \approx 2$ months.

The optimization of the probability of no-failure operation of machines according to the criterion of "total unit costs" can reduce the injury rate in the production of works with technical objects, thereby increasing industrial safety. Justification of indicators and reliability criteria in the framework of increasing the reliability of works leads to a decrease in failures, reduction of losses for repair and recovery of equipment.

Conclusion. Improving the equipment safety and reliability will lead to injury reduction, reliability increase, reduction of the cost of its repair and recovery.

References

1. Kogaev, V.P., Drozdov, Yu.N. Prochnost' i iznosostoykost' detaley mashin. [Strength and wear resistance of machine elements.] Moscow: Vysshaya shkola, 1991, 319 p. (in Russian).

2. Kasyanov, V.E., Dudnikova, V.V. Povyshenie nadezhnosti i effektivnosti raboty mashiny na osnove uvelicheniya ustalostnogo resursa detaley. [Improving the machine reliability and efficiency based on increasing the fatigue life of its elements.] Vestnik mashinostroeniya, 2009, no. 11, pp. 11-15 (in Russian).

3. Rogovenko, T.N., Zaytseva, M.M. Metod polucheniya sovokupnosti konechnogo ob'ema iz maloy vyborki s pomoshch'yu modelirovaniya. [Method for obtaining finite volume set from a small sample through simulation.] Dep. in VINITI, 2008, no. 970, 27 p. (in Russian).

4. Kasyanov, V.E., Rogovenko, T.N., Zaytseva, M.M. Otsenka gamma-protsentnykh znacheniy sovokupnosti konechnogo ob'ema po maloy vyborke dlya prochnosti detaley mashin. [Evaluation of gamma-percentile values of final volume set at small sample for strength of machines elements.] Vestnik Rostovskogo Gosudarstvennogo Universiteta Putey Soobshcheniya, 2010, no. 1, pp. 20-24 (in Russian).

5. Deyvid, G. Poryadkovye statistiki. [Order statistics.] Moscow: Nauka, 1979, 336 p. (in Russian).

6. Korotkiy, A.A. et al. Risk-orientirovannyy podkhod k organizatsii nadzornoy deyatel'nosti v oblasti promyshlennoy bezopasnosti. [Risk-oriented approach to the organization of supervisory activities in industrial safety.] Bezopasnost' trudov v promyshlennosti, 2016, no. 2, pp. 58-63 (in Russian).

Received 01.11.2018
Submitted 01.11.2018
Scheduled in the issue 15.01.2019

Autors:

Zaytseva Marina Mikhaylovna,
associate Professor of the Department of transport systems and logistics, Don State Technical University, (1, Gagarin sq., Rostov-on-Don, 344000, Russia), candidate of techn. sciences,
marincha1@rambler.ru

Megera Gennadiy Ivanovich,
senior Lecturer of the Department of transport systems and logistics, Don State Technical University, (1, Gagarin sq., Rostov-on-Don, 344000, Russia),

Kopylov Fedor Sergeevich,
student, Don State Technical University, (1, Gagarin sq., Rostov-on-Don, 344000, Russia),

Krymskiy Vasiliy Sergeevich,
student, Don State Technical University, (1, Gagarin sq., Rostov-on-Don, 344000, Russia),

UDC 625
DOI 10.23947/2541-9129-2019-2-37-40

MODERN CONDITION MONITORING SYSTEMS OF ELEVATOR UNITS

Khazanovich G.Sh., Apryshkin D.S.
Don state technical University, Rostov-on-Don, Russian Federation

aprechnik@mail.ru
hazanovich@mail.ru

The paper considers the main systems for monitoring elevator equipment condition, their tasks and functionality. The dependence of the degree of elevator load on the number of storeys of the building is considered. The paper provides options for expanding the possibilities of dispatching systems for better safety of elevator structures.

Keywords: elevator, dispatching system, elevator load, maintenance, safety.

УДК 625
DOI 10.23947/2541-9129-2019-2-37-40

СОВРЕМЕННЫЕ СИСТЕМЫ КОНТРОЛЯ СОСТОЯНИЯ ЛИФТОВЫХ УСТАНОВОК

Хазанович Г. Ш., Апрышкин Д. С.
Донской государственный технический университет, г. Ростов-на-Дону, Российская Федерация
aprechnik@mail.ru
hazanovich@mail.ru

Рассмотрены основные системы для контроля за состоянием лифтового оборудования, их задачи и функциональные возможности. Установлена зависимость степени нагружения лифта от этажности здания. Предложены варианты расширения возможностей систем диспетчеризации для более качественного обеспечения безопасности лифтовых сооружений.

Ключевые слова: лифт, система диспетчеризации, нагрузки лифта, техническое обслуживание, безопасность.

Introduction. Every day a large number of people use elevator units to go up the high-rise buildings. At the same time, high-rise construction significantly prevails over low-rise construction. Thus, according to statistics, in 2018 the volume of construction of buildings with a height of 9 or more floors amounted to 86.3 % of the total volume of construction in Russia. Therefore, the number of elevators, both in houses and in institutions is constantly growing. Together with the growth of the number of elevators, the need for quality control of both the elevator units operation and their maintenance and repair increases. To meet these challenges, people use condition monitoring dispatching systems of elevator units [1, 2].

Main part. Currently the market of elevators control systems provides a big number of computer programs: software dispatching complex "OB" [3]; system of elevator dispatching, control, and communications SLDKS-1 [4]; elevators scheduling program MPultPro and others. These systems have a similar set of functions that allows you to control the elevator movement in real time and transmit information to the control panel of the dispatcher, which can simultaneously control several dozens of elevator units in various construction facilities.

The dispatching complex connected to the elevator provides the dispatcher with the following information:

• actuation of electrical safety circuits;
• unauthorized opening of the shaft doors in the normal operation mode;
• opening of the door (cover) of the elevator control device out of the machine room;
• actuation of the emergency call button from the elevator car;
• opening of the door of the machine, block rooms of the elevator, the door at the elevator shaft pit.

In addition, the control complex performs the following functions:

• two-way communication between the control room and the cabin (roof) of the elevator, the control room and the engine room;

• automatic check of the communication path with the elevator car;

• sound and light confirmation of the registration of the dispatcher call to negotiation from the elevator cabin and the machine room;

• remote disconnection of the elevator power supply at the command of the dispatcher;

• backup power to the elevator units from the local bus or from the accumulator battery and signaling the transition to backup power;

• protection of devices against the local bus getting high voltage lightning discharges and induced pulse overvoltage, as well as protection against short circuits on the local bus;

• changing the parameters of the elevator unit using the service tool;

• connection to microprocessor-based elevator control stations via serial interface;

• connection of the yellow and green pictograms in accordance with GOST R 51631-2008 [5];

• monitoring the health of the connected equipment;

• identification of incoming alarm: from what lift and what kind of signal.

As it can be seen from the description of functional capabilities of dispatching systems, they constantly monitor the elevator, as well as solve the problem of ensuring safe functioning of elevator devices. However, these control systems do not control the level of specific load experienced by elevator elements over a period of time. These programs signal to the dispatcher about already occurred failures or emergency, but do not allow generating a report on the loading conditions of elevator elements. The ultimate purpose of such information may be to justify the timing of maintenance or repair work in the inter-service interval, which would increase the level of safety in the operation of elevator units, as well as reduce operating costs. It is obvious that timely and qualitative routine maintenance works, the size and sequence of which have a scientific justification, will significantly reduce the risk of emergencies. At the same time, it should be emphasized that according to the available data [6], the program of service and maintenance of elevators of different number of storeys operating in different loading modes in terms of the number of cycles and the magnitude of the statistically equivalent load on the drive, ropes and other elements, differ little from each other. Thus, the frequency of routine maintenance and repair of identical models of passenger elevators operated under different conditions should be different to ensure a proper level of safe operation. The work [7] proposes a relationship for calculating elevator units equivalent load, taking into account the periodic changes of the load in each cycle and the frequency of use of the system. Equivalent in this case means the load received by all elements of the drive of the elevator taken by the engine shaft.

Fig. 1 demonstrates the results of the implementation of the algorithm of modeling the elevator operation modes using a computer program "Simulation of a passenger elevator" [8].

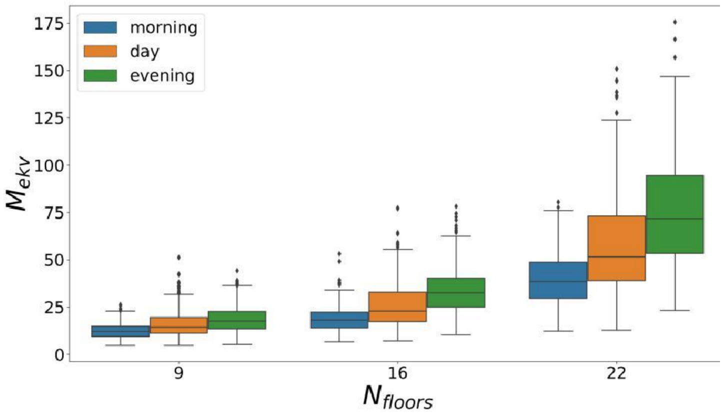


Fig. 1 Distribution of equivalent torques in each cycle of elevator movement: M_{ekv} — equivalent torque on a shaft of the engine; N_{floors} — number of storeys in a building

The study was conducted for three houses with 9, 16 and 22 floors, as well as in three different modes of operation of the elevator: morning, day and evening. The study showed that as the number of floors in a building increases, the dispersion of equivalent torques increases, the upper quartiles shift upwards, and the distributions deviate more and more from the normal pattern and there are many whippings. Evening mode is characterized by the movement of passengers on the upper floors, this leads to an overall increase in the equivalent torque of the engine and, as can be seen from Fig. 1, the evening mode of the building of lower number of storeys is more energy-intensive than the morning mode of the building of higher number of storeys.

Based on the results obtained, it can be concluded that the value of equivalent torques increases disproportionately to the increase in the number of storeys in the building. If the same models are used in buildings with different number of storeys, their operating time before the next maintenance or repair can be significantly different and, therefore, the control of the degree of elevator loading will have a positive impact on ensuring a higher level of safety.

Conclusion. For a more in-depth control over the degree of loading of each individual elevator, it is required to introduce additional controls into the already operating dispatching system. These means will allow fixing so-called equivalent loadings during operation, which can serve as an indicator of an elevator complex condition as a whole and the need of preventive and other types of maintenance works.

References

1. Bezopasnost' liftov. Tekhnicheskiy reglament Tamozhennogo soyuza: TR TS 011/2011. Elektron. fond pravovoy i normativ.-tekhn. dokumentatsii. Konsortsium "Kodeks". [The safety of elevators. Technical regulations of the Customs Union: TR CU 011/2011. Electron. fund of legal and norm.-tech. documents. Consortium "Codex".] Available at: http: // docs.cntd.ru / document / 902307835 (accessed: 11.04.2019) (in Russian).

2. Ob organizatsii bezopasnogo ispol'zovaniya i soderzhaniya liftov, pod'emnykh platform dlya invalidov, passazhirskikh konveyerov (dvizhushchikhsya dorozhek), eskalatorov, za isklyucheniem eskalatorov v metropolitenakh: Postanovlenie Pravitel'stva RF ot 24 iyunya 2017 g. no. 743. Informatsionno-pravovoy portal "Garant.RU". [On the organization of safe use and maintenance of elevators, lifting platforms for disabled people, passenger conveyors (moving footpaths), escalators, except for escalators in subways: Resolution of the Government of the Russian Federation of June 24, 2017 no. 743. Information and legal web portal "Garant.RU".] Available at: https: // www.garant.ru / products/ipo/prime/doc/71607662/ (accessed: 11.04.2019) (in Russian).

3. Dispetcherskiy kompleks "OB'": Rukovodstvo po ekspluatatsii. [Dispatching complex "OB": User's Manual.] OOO Lift-Complex DS. Available at: https: // lkds.ru / upload / docs/pdf/general/RE_3434-001-49739805-07_5.pdf (accessed: 11.04.2019) (in Russian).

4. Sistema liftovogo dispetcerskogo kontrolya i svyazi SLDKS-1: Rukovodstvo po ekspluatatsii. Chast' 1. Tekhnicheskoe opisanie ESAN.484457.001RE. [System of Elevator dispatching, control, and communications SLDX-1: User's Manual. Part 1. Technical description of ESAN.484457.001RE.] MNPP "SATURN". Available at: https://www.mnppsaturn.ru/ftp/public/doc/sldks/re%20sldks-1m%201.pdf (accessed: 11.04.2019) (in Russian).

5. Lifty passazhirskie. Tekhnicheskie trebovaniya dostupnosti, vklyuchaya dostupnost' dlya invalidov i drugikh malomobil'nykh grupp naseleniya: GOST R 51631-2008 (EN 81-70:2003). Natsional'nyy standart Rossiyskoy Federatsii; Federal'noe agenstvo po tekhnicheskomu regulirovaniyu i metrologii. [Passenger elevators. Technical requirements of accessibility, including accessibility for the disabled and other people with limited mobility: GOST R 51631-2008 (EN 81-70:2003). National standard of the Russian Federation; Federal Agency for Technical Regulation and Metrology.] Moscow: Standartinform, 2008, 23 p. (in Russian).

6. Korotkiy, A.A. et al. Analiz chrezvychaynykh proisshestviy na passazhirskikh liftovykh sooruzheniyakh. [Analysis of accidents on passenger lift units.] Nazemnye transportno-tekhnologicheskie kompleksy i sredstva: sb. mezhdunar. nauch.-prakt. konf. [Land transport-technological systems and tools: proc. of intern. sci.-pract. conf.] Tyumen, 2018, pp. 158-162 (in Russian).

7. Khazanovich, G.S., Otrokov, A.V., Aprishrin, D.S. Computer modeling of dynamic processes of passenger elevators at casual external influence. International Multi-Conference on Industrial Engineering and Modern Technologies (FarEastCon). Vladivostok, 2018, pp. 1-6.

8. Khazanovich, G.Sh., Otrokov, A.V., Apryshkin, D.S. Imitatsionnoe modelirovanie raboty passazhirskogo lifta: svidetel’stvo o gosudarstvennoy registratsii program dlya EVM — No.2018664988. [Simulation modeling of the passenger elevator: certificate of state registration of computer programs — No.2018664988.] Rospatent; registration date 27.11.2018.

Received 01.11.2018
Submitted 01.11.2018
Scheduled in the issue 15.01.2019

Об авторах:

Khazanovich G.Sh.,
professor of the Department "Operation of transport systems and logistics», Don State Technical University, (1, Gagarin sq., Rostov-on-Don, 344000, Russia), Doctor of techn. sciences,
hazanovich@mail.ru

Apryshkin D.S.,
senior lecturer of the Department "Operation of transport systems and logistics», Don State Technical University, (1, Gagarin sq., Rostov-on-Don, 344000, Russia),
aprechnik@mail.ru

UDC 519.711.3 +502/504
DOI 10.23947/2541-9129-2019-2-41-45

COMPARATIVE ANALYSIS OF VEHICLES AND STATIONARY SOURCES IMPACT ON THE ATMOSPHERE IN A BIG CITY

Kuren S. G., Gudenko N. E.
Don state technical University, Rostov-on-Don, Russian Federation

sergejgrigorevich@yandex.ru
gudenko.nadyusha@mail.ru

The paper provides the analysis of the results of a multi-year monitoring of pollutant emissions from motor vehicles and stationary sources recorded in Rostov-on-Don. Conclusions on the composition, structure and scope of these emissions are drawn. The authors prepared a database covering 2009-2016 years to build mathematical models of atmospheric air pollution.

Keywords: atmospheric air, surface layer, sources of pollution, motor vehicles, stationary sources, ecology.

УДК 519.711.3 +502/504
DOI 10.23947/2541-9129-2019-2-41-45

СРАВНИТЕЛЬНЫЙ АНАЛИЗ ВОЗДЕЙСТВИЯ АВТОТРАНСПОРТА И СТАЦИОНАРНЫХ ИСТОЧНИКОВ НА АТМОСФЕРУ В БОЛЬШОМ ГОРОДЕ

Курень С. Г., Гуденко Н. Е.
Донской государственный технический университет, г. Ростов-на-Дону, Российская Федерация
sergejgrigorevich@yandex.ru
gudenko.nadyusha@mail.ru

Проведён анализ результатов многолетнего мониторинга выбросов загрязняющих веществ в атмосферу от автотранспорта и стационарных источников, зафиксированных в Ростове-на-Дону. Сделаны выводы по составу и объёму выбросов. Подготовлена база данных за период 2009–2016 годы для построения математической модели загрязнения атмосферного воздуха.

Ключевые слова: атмосферный воздух, приземный слой, источники загрязнения, автотранспорт, стационарные источники**,** экология.

Introduction. Combustion of hydrocarbon and various types of alcohol-containing fuel in automobile internal combustion engines producing toxic products pollutes the air. This leads to the deterioration of environmental condition in large industrial cities, climate change, the disruption of equality in the ecosystem of the region and the deterioration of health of the people living on this territory.

Main part. In Rostov-on-Don, the share of emissions from motor vehicles in total emissions into the atmosphere has increased from 61.1% in the mid-1990s to 97.9% in 2014

The composition of air pollutants in Rostov-on-Don for two periods: 2009-2014 and 2014-2016 [1-3] was studied by statistical methods [1-3]. According to the results of the study, a database was created for the development of a mathematical model of pollution of the atmosphere surface layer by vehicles. The diagrams (Fig. 1, 2) show the results of air emissions analysis in Rostov-on-Don.

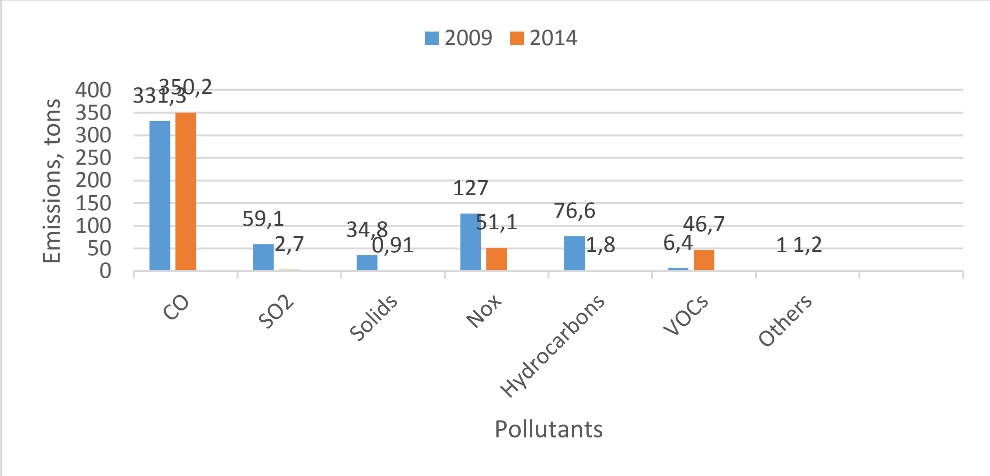


Fig. 1. Composition of pollutants emissions into the atmosphere in 2014 compared to 2009

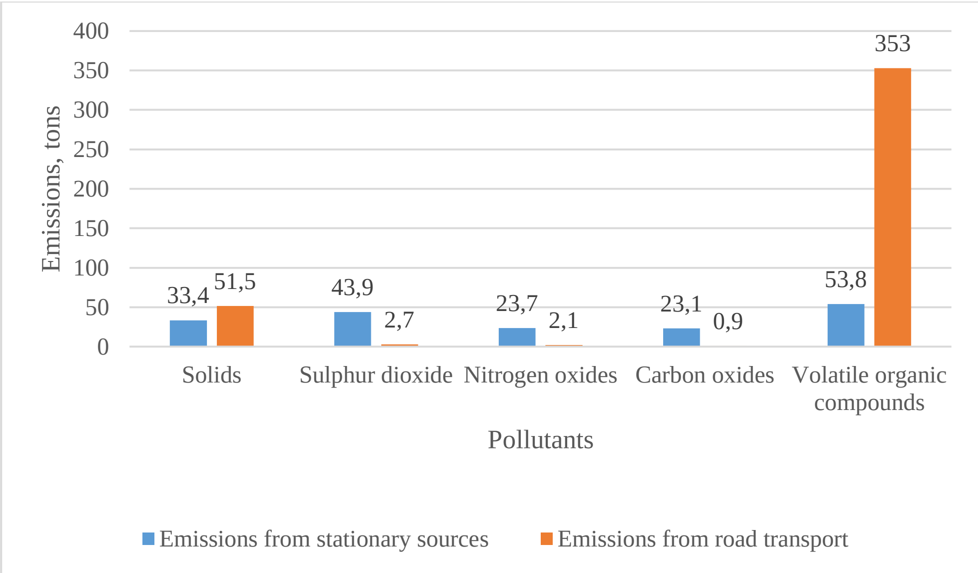


Fig. 2. Composition of pollutants emissions into the atmosphere in 2014 compared to 2009

The diagrams (Fig. 3, 4) show the specific contribution of motor transport to the dynamics of gross emissions (thousand tons) of pollutants into the atmosphere from stationary and mobile sources of pollution in Rostov-on-Don in 2009-2016.

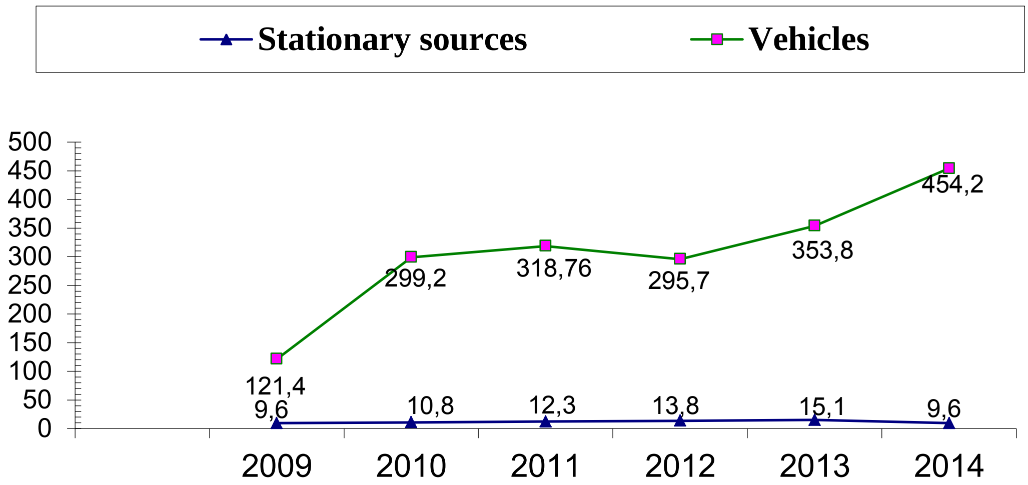


Fig. 3. Air emissions in Rostov-on-Don (thousand tons) in 2009-2014

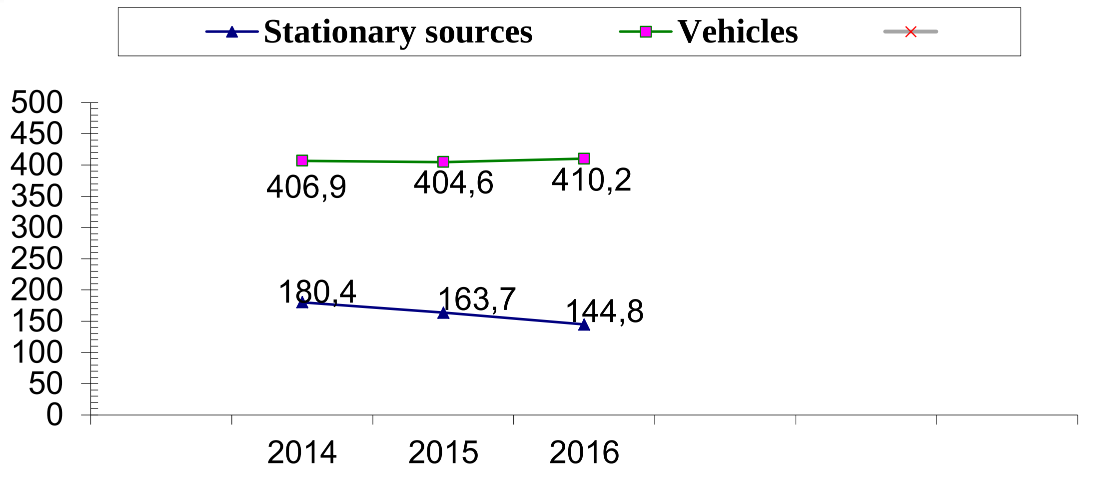


Fig. 4. Air emissions in Rostov-on-Don (thousand tons) in 2014-2016

Over the study period, there were two stages in the development of environmental protection in relation to the level of air pollution by vehicles. At the same time, the chemical composition of emissions depends on the growth of qualitative and quantitative composition of the vehicle park, as well as on the established requirements for imported cars, the requirements for their quality and compliance with environmental safety, and, finally, the requirements for the quality of hydrocarbon fuel produced in our country for cars [4-14].

In Rostov-on-Don in 2009-2014, there was a sharp increase in vehicles emissions. The emissions include carbon oxides, phenol, formaldehyde, other volatile organic compounds, as well as soot. All this is related directly to the significant increase in the operated fleet of vehicles and their non-compliance with the environmental requirements. At the same time, there is a decrease in the level of pollution with sulfur dioxide, nitrogen oxide, hydrogen sulfide and benzpyrene. During 2014-2016, the situation changed for the better. The growth of emissions into the atmosphere from road transport slowed down, which clearly demonstrates the effect of the decisions taken at the state level to limit the import of second-hand cars and to improve the quality of hydrocarbon fuel.

Conclusion. The data obtained demonstrate the dependence of the volume and structure of emissions that pollute the atmosphere on the qualitative and quantitative composition of the city's car park. The authors intend to create a mathematical model of pollution of the atmosphere surface layer in urban conditions, which can be used to predict the dynamics of the process. The solutions to this task will contribute to the implementation of measures to reduce the negative impact of emissions on the environment, which is a priority direction of modern environmental policy.

References

1. Gosudarstvennyy doklad "O sostoyanii okruzhayushchey prirodnoy sredy Rostovskoy oblasti v 2020 godu". Administratsiya Rostovskoy oblasti, Departament prirodnykh resursov po Yuzhnomu regionu; pod. obshch. red. V.P. Vodolatskogo, P.P. Ulyanova, M.V., Parashchenko. [State report "On the state of the environment of the Rostov region in 2000". Administration of the Rostov region, Department of natural resources in the Southern Region; under the general ed. of Vodolatskiy, V.P., Ulyanov, P.P., Parashchenko M.V.] Rostov-on-Don: LLC "Sintez tekhnologiy", 2001,136 p. (in Russian).

2. Ekologicheskiy vestnik Dona "O sostoyanii okruzhayushchey sredy i prirodnykh resursov Rostovskoy oblasti v 2009 godu". [Ecological Bulletin of the Don "On the state of the environment and natural resources of the Rostov region in 2009".] Ministry of Natural Resources and Ecology of the Rostov region. Available at: https://минприродыро.рф/projects/19/?nav-documents=page-1 (accessed: 11.04.2019) (in Russian).

3. Ekologicheskiy vestnik Dona "O sostoyanii okruzhayushchey sredy i prirodnykh resursov Rostovskoy oblasti v 2015 godu". [Ecological Bulletin of the Don "On the state of the environment and natural resources of the Rostov region in 2015"] Ministry of Natural Resources and Ecology of the Rostov region. Available at: https://минприродыро.рф/projects/19/?nav-documents=page-1 (accessed: 11.04.2019) (in Russian).

4. Ekologicheskiy vestnik Dona "O sostoyanii okruzhayushchey sredy i prirodnykh resursov Rostovskoy oblasti v 2017 godu". [Ecological Bulletin of the Don "On the state of the environment and natural resources of the Rostov region in 2017".] Ministry of Natural Resources and Ecology of the Rostov region. Available at: https://минприродыро.рф/projects/19/?nav-documents=page-1 (accessed: 11.04.2019) (in Russian).

5. Kuren, S.G. et al. Modelirovanie protsessov zagryazneniya vozdukha. [Modeling of air pollution processes.] Izvestiya Vuzov. Severo-Kavkazskii Region. Series "Natural sciences", 2014, no. 4 (182), pp. 78-81 (in Russian).

6. Zubareva, E.G., Kuren. S.G., Yurtaev, A.A. Ekologicheskiy monitoring toksichnosti otrabotavshikh gazov avtomobiley v YUFO. [Ecological monitoring of toxicity of vehicle exhaust gases in the Southern Federal District] Engineering journal of Don, 2018, no. 1. Available at: ivdon.ru/ru/magazine/archive/n1y2018/4642 (accessed: 11.04.2019) (in Russian).

7. Kuren, S.G. et al. Evolutsiya khimicheskogo sostava vybrosov zagryaznyayushchikh veshchestv v atmosfery v gorode-millionnike. [Evolution of chemical composition of pollutants emissions into the atmosphere in a city with more than 1 million inhabitants.] Engineering journal of Don, 2018, no. 2. Available at: IVD_30_Kuren_Zubareva.pdf_d2e48fd41d.pdf (accessed: 11.04.2019) (in Russian).

8. Kuren, S.G., Ryabykh, G.Yu., Yurtaev, A.A. Analiz zagryazneniya okruzhayushchey sredy na osnove matematicheskikh modeley. [Mathematical models analysis of environmental pollution.] Innovatsionnye tekhnologii v nauke i obrazovanii (ITNO-2017): materialy V mezhdunar. nauch.-prakt. conf. [Innovative technologies in science and education (ITNO-2017): materials of V international. sci.-pract. conf.] Rostov-on-Don, 2017, pp.147-150 (in Russian).

9. Kuren, S.G. et al. Razrabotka modeli, opisyvayushchey protsess zagryazneniya vozdukha. [Development of a model describing the process of air pollution.] Perspektivy razvitiya nauki i obrazovaniya: sb. trudov mezhdunar. nauch.-prakt. konf. [Development prospects of science and education: proceedings of the international. sci.-pract. conf.] Tambov, 2012, vol.13, pp. 77-78 (in Russian).

10. Kuren, S.G. et al. Puti snizheniya toksichnosti otrabotavshikh gazov avtomobiley. [Ways to reduce the toxicity of exhaust gases of vehicles.] Sovremennye tendentsii razvitiya nauki i tekhnologiy: sb. trudov VII mezhdunar. nauch.-prakt konf. [Modern trends in science and technology: proceedings of the VIII intern. sci.-pract. conf.] Belgorod, 2015, vol. 8, pp. 120-122 (in Russian).

11. Kuren, S.G., Ryabykh, G.Yu., Beluzhenko, O.V. Matematicheskoe modelirovanie i prognozirovanie atmosfernykh zagryazneniy. [Mathematical modeling and forecast of atmospheric pollutants.] Aktual'nye zadachi matematicheskogo modelirovaniya i informatsionnykh tekhnologiy: materiyaly mezhdunar. nauch.-prakt. konf. [Actual problems of mathematical modeling and information technologies: proceedings of intern. sci.-pract. conf.] Sochi, 2017, pp. 48-50 (in Russian).

12. Kuren, S.G. et al. Issledovanie dannykh dlya postroeniya matematicheskoy modeli zagryazneniya atmosfery. [Data research for the construction of a mathematical model of air pollution.] Sovremennye tendentsii razvitiya nauki i tekhnologiy: sb. trudov XI mezhdunar. nauch.-prakt. konf. [Modern trends in the development of science and technology: proceedings of XI international. sci.-pract. conf.] Belgorod, 2016, no. 2-2, pp. 134-137 (in Russian).

13. Kuren, S.G. et al. Matematicheskaya model' zagryazneniya atmosfery. [Mathematical model of atmospheric pollution.] Innovatsionnye tekhnologii v nauke i obrazovanii (ITNO-2015): sb. trudov

mezhdunar. nauch. conf. [Innovative technologies in science and education (ITNO-2017): proceedings of the internat. sci. conf.] Zernograd, 2015, pp. 363-366 (in Russian).

14. Kuren, S.G. et al. Matematicheskaya obrabotka dannykh po zagryazneniyu atmosfery. [Mathematical processing of data on atmospheric pollution.] Dinamika tekhnicheskikh system: sb. trudov XII mezhdunar. nauch.-tekhnic. konf. [Dynamics of technical systems: proceedings of XII internat. sci.-techn. conf.] Rostov-on-Don, 2016, pp. 359-362.

Received 01.11.2018
Submitted 01.11.2018
Scheduled in the issue 15.01.2019

Autors:

Курень Сергей Григорьевич,
associate professor, Don State Technical University, (1, Gagarin sq., Rostov-on-Don, 344000, Russia), Candidate of techn. sciences,
sergejgrigorevich@yandex.ru

Гуденко Надежда Александровна,
student, Don State Technical University, (1, Gagarin sq., Rostov-on-Don, 344000, Russia),
gudenko.nadyusha@mail.ru

UDC 656.089
DOI 10.23947/2541-9129-2019-2-46-51

TRAFFIC ACCIDENTS: MAIN CAUSES, ACCIDENTS ANALYSIS, REDUCTION METHODS

Korotkiy A.A., Bakhteyev O.A.
Don state technical University, Rostov-on-Don, Russian Federation

korot@novoch.ru
omp-rostov@list.ru

This article analyzes traffic accidents in the Rostov region in 2018, their main causes, dependence on time of day, driving experience, age of drivers. Methods for reducing accident rates are proposed. There is a decrease in the number of road accidents compared with 2017 on the example of statistical data provided by the State Road Transport Inspectorate and posted on the Internet. Options for conducting additional internships, contests of knowledge of the road traffic regulations, driving skills competitions, road rally, methods of speed limit remote control, comfortable driving, introduction of driver physical monitoring systems, introduction of vehicle technical condition monitoring systems, fault indication systems are considered. Special attention is given to the use of risk-based approach in road transport enterprises and risk class reduction.

Keywords: traffic accident, accident, accident rate on transport, reduction methods, electronic devices, risk-based approach.

УДК 656.089
DOI 10.23947/2541-9129-2019-2-46-51

ДОРОЖНО-ТРАНСПОРТНЫЕ ПРОИСШЕСТВИЯ: ОСНОВНЫЕ ПРИЧИНЫ, АНАЛИЗ АВАРИЙНОСТИ, МЕТОДЫ СНИЖЕНИЯ

Короткий А. А, Бахтеев О. А.
Донской государственный технический университет, г. Ростов-на-Дону, Российская Федерация
korot@novoch.ru
omp-rostov@list.ru

Анализируются дорожно-транспортные происшествия в Ростовской области за 2018 год, их основные причины, зависимость от времени суток, водительского стажа, возраста водителей, предлагаются методы снижения аварийности. Отмечается снижение количества дорожно-транспортных происшествий по сравнению с 2017 годом на примере статистических данных, предоставленных государственной автомобильной инспекцией и размещенных в сети интернет. Рассматриваются варианты проведения дополнительных стажировок, конкурсов знаний «Правил дорожного движения», соревнований по мастерству вождения, по дорожному ралли. Предложены методы дистанционного контроля скоростного режима, комфортного вождения. Рассмотрена целесообразность внедрения систем контроля физического состояния водителя и технического состояния транспортного средства, систем индикации неисправностей. Отдельно рассматриваются применение риск-ориентированного подхода в автотранспортных предприятиях и снижение класса риска.

Ключевые слова: дорожно-транспортное происшествие, ДТП, аварийность на транспорте, методы снижения, электронные устройства, риск-ориентированный подход.

Introduction. Table 1 presents information on accidents on the Rostov region roads in 2017-2018. It includes the total number of cases of road traffic accidents (RTA), cases of injury and death of road users. It provides comparative data (in percentage form) in relation to the last year's period (LYP).

Table 1

Number of accidents on the roads of the Rostov region

Indicator name	RTA	± % LYP	dead	± % LYP	injured	± % LYP
Number of accidents in 2017	4626	–7.1	598	–16.0	5838	–4.4
Number of accidents in 2018	3925	–15.2	554	–7.4	4860	–16.8

Despite the overall dynamics of reducing the number of road traffic accidents in 2018 compared to 2017, their total number remains very impressive. In 2018 in the Rostov region, there were 3925 accidents in which 554 people died and 4860 people were injured. The number of accidents involving children under 16 years - 378, 19 children died and 403 children were injured in these accidents. Every day people die on the Rostov region roads. What are the causes of these accidents? Analyzing the statistics [1], it can be noted that the maximum number of accidents occur both in dinner time and in the evening rush hours, which can be explained by the general fatigue of drivers. Table 2 shows the number of accidents at different times of day.

Table 2

Road traffic accidents by the time of their occurrence

Time of the day interval	00–01	01–02	02–03	03–04	04–05	05–06	06–07	07–08	08–09	09–10	10–11	11–12
Number of accidents	90	74	55	58	52	46	101	173	187	183	169	199

Continuation of table 2

Time of the day interval	12–13	13–14	14–15	15–16	16–17	17–18	18–19	19–20	20–21	21–22	22–23	23–24
Number of accidents	202	194	194	225	212	272	282	249	227	181	168	132

Tables 3-5 provide data on the number of accidents due to traffic violations (traffic rules), depending on the type of vehicle, intoxication, age and drivers’ experience.

Table 3

Number of accidents for different types of vehicles and drivers in a state of intoxication

Types of vehicles and drivers in a state of intoxication	Number of accidents
All types of vehicles	3334
Cars	2716
Cars with drivers in the state of intoxication	196
Trucks	266
Trucks with drivers in the state of intoxication	5
Buses	73
Buses with drivers in the state of intoxication	2

Types of vehicles and drivers in a state of intoxication	Number of accidents
Motorcycles	89
Motorcycles with drivers in the state of intoxication	28
Mopeds and equivalent vehicles	55
Trams	1
Trams with drivers in the state of intoxication	0
Trolleybuses	3
Trolleybuses with drivers in the state of intoxication	0
Tractors and other self-propelled machinery	11
Tractors and other self-propelled machinery with drivers in the state of intoxication	1

Table 4

Age of drivers, years	00–10	10–14	14–16	16–18	18–21	21–25	25–30	30–40	40–50	50–60	60–70	More than 70
Number of accidents	0	5	6	16	165	287	464	916	593	399	247	72

Table 5

Driving experience, years	До 2	2–5	5–10	10–15	More than 15
Number of accidents	229	397	655	459	

Summarizing the information presented in tables 2-5, it is worth noting that 3334 accidents occurred because of traffic violations by drivers. Of these, drivers of cars — 2716 accidents, drivers of trucks — 266 accidents and bus drivers — 73 accidents. The number of bus passengers' casualties amounted to 9 people, which is 40 % less than in 2017. Some sources claim that the younger the driver is, the more likely he is to become the culprit of an accident [2]. Statistics say the opposite. The number of accidents with drivers from 18 to 25 years is 452 cases, and at the age of 25 to 30 years — 464 cases, in the age group from 30 to 40 years — 916 cases. With the further increase in the age of drivers, the number of accidents gradually decreases. Therefore, for the age group from 40 to 50 years, the number of accidents is 599, and for the group from 50 to 60 years, this figure is 399. The biggest number of accidents caused by drivers is observed among the drivers with long work experience (over 15 years) — 1427 cases. For drivers with experience less than 2 years, there were only 229 accidents. 244 accidents were drunken-driving accidents; in 80 cases drivers refused to undergo a medical examination.

Table 6 presents statistical data on the most typical emergencies associated with road accidents. It considers 3925 cases. Among them 995 people were injured in accidents, at the place of which there were

violations of the mandatory requirements for the operating condition of automobile roads and railway crossings under the conditions of ensuring road safety (RS).

Table 6

Accident circumstances and the number of the injured

Accident circumstance	Number of the injured
Collision of vehicles	1782
Overturning of vehicles	225
Collision with a standing vehicle	188
Automobile-pedestrian accident	1096
Collision with an obstacle	250
Automobile-bicyclist accident	117
Collision with animal-drawn transport	0
Passenger drop	98
Collision with an animal	3
Other types of circumstances	166

Table 6 shows that the maximum number of the injured (1782) was in car collisions. The second place was automobile-pedestrian accident — 1096 cases. The third most common accident — violation of the operational condition of roads and railway crossings to comply with road safety — 995 cases. Attention is also drawn to the increase in the number of accidents caused by the operation of technically defective vehicles. In 2018, there was an increase of 53.8% compared to the same indicator last year.

Conclusion. Possible ways to reduce the number of accidents:

• assessment of traffic rules knowledge. It may be voluntary, organizing knowledge competitions in road transport companies, as well as arranging competitions for motorists as road rally. Drivers working in road transport enterprises should regularly undergo training on traffic rules knowledge. For unemployed drivers with experience over 15 years and age over 35 years, it is recommended to introduce a mandatory test of traffic rules knowledge, for example, with periodic reissue of the driver's license. The incentive to comply with the traffic rules is also the presence on the vehicles of transport enterprises phones with the person responsible for the observation of traffic rules or the dispatcher, given the fact that any person who recorded the fact of traffic rules violation by the car of the enterprise can call them;

• driving quality improvement. To this extent, it is necessary to include the organization of courses of driving maneuvers training of motorists and employees of enterprises working on certain vehicles, as well as driving competitions for motorists and between motor transport enterprises. In addition, it is possible to carry out such activities as cultural events (family events) for family members of employees of

motor transportation enterprises [3]. An important factor is the installation of critical acceleration sensors on vehicles, which could record motion smoothness of these vehicles. For vehicles, carrying passengers and heavy goods, especially in a liquid state, the installation of such sensors should be mandatory;

• organization of systems that monitor physical well-being of drivers. If a driver violates work-rest schedule, or just suddenly feels bad, but continues to drive a vehicle — it can lead to a tragedy. On trucks weighing more than 3.5 tons, on buses and cars carrying passengers, it is necessary to provide an alcohol-screening device that activates periodically [4]. Information on exceeding the safe threshold values of these parameters should be displayed on the dispatcher control unit of the motor transport enterprise and on the external light indicator installed on the car, as well as on the information board in the cabins of cars carrying passengers;

• installation of systems that control the car speed and its technical condition. The systems should transmit data to motor transport enterprises on the vehicle speed, on its technical serviceability [5]. Information on exceeding the safe threshold values should also be sent to the dispatcher control unit of the motor transport enterprise and the external light indicator on the vehicle, as well as to information boards in the cabins of cars carrying passengers;

• weekly monitoring of roadway and road equipment state for compliance with the requirements for the operational state of roads and railway crossings to comply with road safety.

Achieving all of the above-mentioned things will help to increase the level of safety of road transport enterprises and to reduce the hazard class resulting from the application of the risk-based approach.

References

1. Pokazateli sostoyaniya bezopasnosti dorozhnogo dvizheniya. [Road safety indicators.] Official website of the State Road Traffic Safety Inspectorate. Available at: http://www.stat.gibdd.ru (accessed: 11.04.2019) (in Russian).

2. Ryabokonenko, K.R. Analiz zavisimosti vozrasta i stazha voditelya na bezopasnoe upravlenie avtomobilem. [Analysis of the dependence of a driver's age and experience on safe driving.] Logistika – evraziyskiy most: materialy 10-y mezhdunar. nauchn.-prakt. konf. [Logistics— Eurasian bridge: proc. of 10th international. sci.-pract. conf.] Krasnoyarsk, 2015, pp. 537-541 (in Russian).

3. Polozhenie o povyshenii professional'nogo masterstva i stazhirovke voditeley: RD 200–RSFSR–12–0071–86–12. [Regulations on improvement of drivers' professional skills and training: RD 200–RSFSR–12–0071–86–12.] Elektron. fond pravovoy i normativ.-tekhn. dokumentatsii. Konsortsium "Kodeks". [Electron. fund of legal and norm.-tech. documentation. Consortium "Kodeks".] Available at: http://docs.cntd.ru/document/420362948 (accessed: 11.04.2019) (in Russian).

4. Bakhteyev, O.A., Mironov, A.V. Primenenie sitem kontrolya fizicheskogo sostoyaniya vodeteley. [Use of drivers' physical well-being control systems.] Nazemnye transportno-tekhnologicheskie kompleksy i sredstva: materialy mezhdunar. nauchn.-tekhn. konf. [Ground transport-technological systems and tools: proc. of internat. sci.-techn. conf.] Tyumen, 2018, pp. 47-51 (in Russian).

5. Korotkiy, A.A. et al. Snizhenie kategoriy riska transportnykh predpriyatiy putem vnedreniya ustroystv monitoringa i kontrolya. [Reduction of risk categories of transport enterprises through the intro-

duction of monitoring and control devices.] Molodoy issledovatel' Dona, Rostov-on-Don, 2018, no. 4(13), pp. 69-73 (in Russian).

Received 01.11.2018
Submitted 01.11.2018
Scheduled in the issue 15.01.2019

Autors:

Korotkiy Anatoliy Arkadyevich,
head of the Department "Operation of transport systems and logistics", Don State Technical University, (1, Gagarin sq., Rostov-on-Don, 344000, Russia), doctor of techn. sciences,
korot@novoch.ru

Bakhteyev Oleg Ayratovich,
assistant of the Department "Operation of transport systems and logistics", *Don State Technical University, (1, Gagarin sq., Rostov-on-Don, 344000, Russia),*
omp-rostov@list.ru

UDC 62-781
DOI 10.23947/2541-9129-2019-2-52-57

TECHNICAL DECISIONS IN UNCERTAIN ENVIRONMENT AT RISK

Deryushev V. V., Kosenko E.E., Kosenko V.V., Zaytseva M.M.
Don state technical University, Rostov-on-Don, Russian Federation

deryushevv@mail.ru
A123lok@mail.ru
kosenko_verav@mail.ru
marincha1@rambler.ru

A model has been built for estimating the degree of uncertainty in making technical decisions. It is based on a comparison of the results of decisions made (training sample) with their assessment based on indicators adopted for the intended decision making.

Keywords: operational safety, risk minimization, uncertainty, decision making, training sample, replacement function, quantitative risk assessment.

УДК 62-781
DOI 10.23947/2541-9129-2019-2-52-57

ПРИНЯТИЕ ТЕХНИЧЕСКИХ РЕШЕНИЙ В УСЛОВИЯХ НЕОПРЕДЕЛЕННОСТИ ПРИ НАЛИЧИИ РИСКА

Дерюшев В. В., Косенко Е. Е., Косенко В. В., Зайцева М. М.
Донской государственный технический университет, г. Ростов-на-Дону, Российская Федерация
deryushevv@mail.ru
A123lok@mail.ru
kosenko_verav@mail.ru
marincha1@rambler.ru

Построена модель оценивания степени неопределенности при принятии технических решений. Она основана на сравнении данных обучающей выборки с их оценкой по предлагаемым в модели показателям.

Ключевые слова: безопасность эксплуатации, минимизация риска, неопределенность, принятие решений, обучающая выборка, замещающая функция, количественная оценка риска.

Introduction. Nowadays in engineering practice, it is increasingly necessary to make decisions in uncertain environment, when the consequences of decisions are associated with a particular risk. The risks in this case include the possibility of accidents, catastrophes and other events defined by the concept of "operational safety". It is obvious that in making certain technical decisions in uncertain environment, the risk cannot be fully excepted. Informed risk-taking and its minimization should be taken into account in modern conditions, avoiding its complete disregard. Moreover, it may sometimes be beneficial not to minimize the risk but to allow some level of risk, especially in uncertain environment, in order to increase the overall usefulness of the decision. This is due to the fact that risk-free decision-making, for example, from an extremely pessimistic position with maximum caution, is usually unprofitable. In the scientific approach, the decision must be taken from the position of assessing the quantity of risk, which has a given boundary when achieving the result with the necessary certainty. The solutions described below are aimed at ensuring the effectiveness of technical decision-making in uncertain environment with a calculated risk.

The concept of risk and uncertainty. The technical decision taken in situations involving risk, in addition to the desired positive result, necessarily leads to any losses (financial, material, temporary, etc.). The cost depends on external conditions (effects), and this dependence is not probabilistic, but possible, especially with single decisions. In the field of engineering practice, the concept of risk has the meaning of "responsibility for the decision" [1]. And this responsibility is connected, first of all, with the life and health of people. In all cases, in accordance with the requirements of modern science, the concept of risk should make it possible to quantify it. In the future, the risk will be understood as the value that character-

izes the possibility of obtaining an undesirable result in the considered situation of decision-making. In particular, in [1] it is proposed to determine the amount of risk as a product of the value of the undesirable result (or an event uniquely associated with this result) by the possible extent to achieve it (or the possible extent of the occurrence of the corresponding event). Therefore, to quantify the risk, let us first assume that each considered variant of the A_i decision from a finite set of variants $A_1, A_2, \ldots, A_i, \ldots, A_m$ is uniquely associated with some undesirable result depending on the external conditions (effects) of F_j. In general, in uncertain environment, the set of external conditions F is described by fuzzy set theory and is also finite, although it is principally possible to consider an infinite fuzzy set of external conditions $F_1, F_2, \ldots, F_j$. Next, we will consider the situation of decision-making, when considering obviously unacceptable options we will need to make a choice. We believe that the results contained in the set A will meet the conditions with a positive outcome. In this case, the problem of decision-making is to reduce the probability of large losses when choosing an alternative from the set A of the following form [2]:

$$A_i = (e_{i1}, p_{i1}; \ldots; e_{ij}, p_{ij}; \ldots),\ i = 1, 2, \ldots, m,$$

where e_{ij} is the loss that occurs when the j-th external conditions, $j = 1, 2, \ldots, n$; p_{ij} — the possibility of realization of the j-th external conditions when making the i-th desicion.

As shown in [2], the goal (reducing the possibility of large losses) can be achieved if the risk assessment of the i-th decision as a measure of the possibility of realization of certain losses $\boldsymbol{e}$ use a special replacement function $P_i(e)$, reflecting (as accurately as possible) the possibility of large losses [3-5].

Construction of compensatory functions in uncertain environment

A compensatory function must meet the following requirements [2].

First, the function $P_i(e)$ must belong to such a family of functions defined on the $\boldsymbol{e}$ axis $f(e, h)$ with the parameter h, at which one of the following conditions must be satisfied for all e from the interested to us area:

$$\text{if } h_a > h_b, \text{ then } f(e, h_a) \geq f(e, h_b);$$

$$\text{if } h_a > h_b, \text{ then } f(e, h_a) \leq f(e, h_b).$$

Second, the values of the compensatory function $P_i(e)$ and function $f(e, h)$ should lie in the following interval

$$0 \leq f(e, h_b) \leq 1.$$

The first two requirements are obvious. When formulating the third requirement, we note that the compensatory function should reflect the possibility of large losses with increasing uncertainty in decision-making. Therefore, it is advisable to formulate the third requirement in the following form:

$$P_i(e) = f(e, h_i),$$

where h_i is the value of the parameter h at which the difference between the functions $f(e, h)$ and $P_i(e)$ is minimal for all the values of h in the H_i area where the condition is satisfied:

$$f(e, h) \geq P_i(e).$$

This means that the function f (e, h) provides the highest accuracy of the upper limits of the possibility of large losses with increasing uncertainty. To satisfy the last requirement, a special function was introduced in [2]:

$$q(p, B) = (1 - B \times \ln p)^{-1/B})$$

The value p here is the value of the compensatory function $P_i(e)$, i.e. in this case $p = P_i(e)$. B parameter determines the degree of uncertainty in the considered decision-making situation.

According to the condition (2), the value of p lies in the range $0 \leq p \leq 1$, therefore, the function $q(p, B)$ is always non-negative and its values also lie in the interval [0,1]. It follows that for all the losses e from the range of values E,

$$\text{if } P_i(e) = P_j(e), \text{ then } q[P_i(e), B] = q[P_j(e), B]$$

$$\text{and if } P_i(e) > P_j(e), \text{ then } q[P_i(e), B] \geq q[P_j(e), B].$$

Therefore, when assessing the risk, the comparison of compensatory functions $P_i(e)$ can be reduced to a comparison of functions $q[P_i(e), B]$, which in this case can also be a measure of the possibility of the i-th event associated with losses **e** [6-9].

The value B can take any value in the interval [0, +□]. Moreover, the greater the value of B, the greater the degree of uncertainty in the decision.

Risk assessment in uncertain conditions

Now previous considerations allow us to move on to the quantitative assessment of risk. According to the definition introduced earlier, risk is the product of the amount of loss **e** received as a result of a decision, by the extent of the possibility of occurrence of the event associated with this decision, i.e.

$$r = e \times q(p, B). \quad (6)$$

Given that $p = P_i(e)$, and the compensatory function is subject to the above requirements, the amount of risk must belong to a certain set of R_i, which can be expressed [10-13] as follows:

$$R_i = \{r | r \in R^+ \cap \forall e \in E\ r \geq e \times q[P_i(e), B]\}. \quad (7)$$

To perform the inequality included in (7), it is necessary to consider the behavior of the compensatory function $P_i(e)$. When the value of losses in the interval $e_{ij-1} \leq e \leq e_{ij}$ ($j = 2, ..., n$), the function retains a constant value, i.e. $P_i(e) = const$. When the value of losses reaches the set values, i.e. at $e = e_{ij}$ the function $P_i(e)$ decreases abruptly. Hence, the maxima of the function $r = e \times q[P_i(e), B]$ correspond to abscissae $e = e_{i1}, e_{i2}, \ldots, e_{in}$. It follows that the maximum risk value is determined by the formula

$$\max(r) = \max\{e \times q[P_i(e), B]\} = \max\{e_{ij} \times q[P_i(e), B]\}, \quad (8)$$
$$e \in E\ e \in E\ j \in N_i,$$

where $N_i = \{j \mid e_{ij} \in E\}$.

It is obvious that the inequality $r \geq e \times q[P_i(e), B]$ is equivalent to the inequality

$$r \geq \max\{e \times q[P_i(e), B]\},\ e \in E$$

Then, given (8), the expression (7) will take the form

$$R_i = \{r | r \in R^+ \cap r \geq h_i\}, \quad (9)$$

where $h_i = \max\{e_{ij} \cdot q[P_i(e_{ij}), B]\}.\ j \in N_i$

In addition, in order to meet the requirements for the compensatory function, it is necessary that [2]:

$$f(e, h) = 1 \text{ at } e \leq h, (10)$$
$$f(e, h) = \exp(-1/B) \cdot \exp[-1/B(e/h)^B] \text{ at } e \geq h$$

This implies the correctness of the first condition (1), i.e. if $h_a > h_b$, then

$$f(e, h_b). \quad (11)$$

When assessing the risk of the i-th decision, it is necessary to choose the minimum value among the whole set of risk values $r \in R_i$. Then it follows from (9) and (11) that

$$r_i = \min r = h_i \quad (12)$$

Thus, taking into account (5), (9) from the expression (12) it follows that the value of the risk of the i-th decision is determined by the formula

$$r_i = \max\{e_{ij}[1 - B \cdot \ln P_i(e_{ij})]^{-1/B}\}. \quad (13)$$
$$r \in R_i$$

To determine the parameter *B*, a finite set *P* of so-called training objects should be given, the level of safety of operation of which is objectively known and can be estimated by a numerical indicator. This allows us to form a kind of approximating objectively existing reality (training) matrix of paired relationships between these objects [14]:

$$Q = \|q_{rk}\|_{p,p}$$

The size of the square symmetric matrix Q is determined by the number p of the considered training objects from the set P, and its elements q_{rk} are the known squares of distances between the r-th and the k-th training objects on the axis of preference from the safety point of view [15, 16].

To construct the relation S on pairs of training objects, we determine the square of the distance between the r-th and the k-th training objects on the z-axis by the formula:

$$s_{rk}(b) = (z_r - z_k)^2 = \left[\sum_{j=1}^{m} b_j \left(x_{rj} - x_{rj}\right)\right]^2 .$$

Then the observed structure of relationships between training objects on the z-axis

$$S(b) = \left\| s_{rk} \right\|_{p,p} .$$

The vector b is fixed.

We will assess compliance with the functional.

$$B = \sum_{r=1}^{p-1} \sum_{k=r+1}^{p} \left[s_{rk}(b) - q_{rk} \right]^2 .$$

The value of this functional shows the degree of uncertainty in the evaluation of the decision-making results.

The structure of relationships between training objects and the relationships observed on the z-axis of the structure are discussed above.

Conclusion. The assessment model of the degree of uncertainty in technical decision-making is constructed. It is based on a comparison of the training sample data with their assessment by the proposed indicators in the model.

References

1. Kini, R.L., Rayfa, Kh. Prinyatie resheniy pri mnogikh kriteriyakh: predpochteniya i zameshcheniya: per. s angl. [Decision-making at many criteria: preferences and substitution: translation from English.] Moscow: Radio i svyaz’, 1981, 560 p. (in Russian).

2. Deryushev, V.V., Sidelnikova, E.G. Obobshchennyy pokozatel’ dostatochnosti dlya otsenivaniya tekhnicheskogo sostoyaniya stroitel’noy i pod’emno-trasportnoy. [Generalized index of sufficiency for the evaluation of the technical condition of construction and handling equipment.] Nauchnoe obozrenie, 2013, no. 9, pp. 164-167 (in Russian).

3. Aven, P. O. Postroenie integral’nogo pokazatelya v kriterial’nom prostranstve. [Construction of the integral index in the criterion space.] Avtomatika i telemekhanika, 1985, no. 4, pp. 87-91 (in Russian).

4. Kasyanov, V.E., Rogovenko, T.N. Metod polucheniya sovokupnosti konechnogo ob’ema srednevzveshennykh napryazheniy v detalyakh mashin. [Method for obtaining a set of finite volume of weighted average stresses in machine elements.] Vestnik of DSTU, 2010, vol. 10, no. 1(44), pp. 91-94 (in Russian).

5. Deryushev, V.V., Sidelnikova, E.G., Zaytseva, M.M. Metod analiza ierarkhiy razdelyayushchikh priznakov stroitel’nykh i pod’emno-transportnykh mashin. [Method of analysis of hierarchies of multiple signs of construction and handling machines.] Stroitel’stvo. Dorogi. Transport: mat-ly mezhdunar. nauch.-prakt. konf. [Construction. Roads. Transport: proc. of internat. sci.-pract. conf.] Rostov-on-Don, 2015, pp. 129-130 (in Russian).

6. Zade, L.A. Ponyatie lingvisticheskoy peremennoy i ego primenenie k prinyatiyu priblizhennogo resheniya. [Concept of a linguistic variable and its application to making an approximate decision.] Moscow: Mir, 1976, 165 p. (in Russian).

7. Deryushev, V.V., Sidelnikova, E.G. Struktura i model’ postroeniya integral’nogo pokazatelya dlya otsenivaniya kachestva stroitel'noy i pod’emno-transportnoy tekhniki. [Structure and model of con-

struction of an integral indicator for assessing the quality of construction and lifting and transport equipment.] Nauchnoe obozrenie, 2013, no. 9, pp. 311-313 (in Russian).

8. Korotkiy, A.A. et al. Risk-orientirovannyy podkhod k organizatsii nadzornoy deyatel'nosti v oblasti promyshlennoy bezopasnosti. [Risk-oriented approach to the organization of supervisory activities in the field of industrial safety.] Bezopasnost' truda v promyshlennosti, 2016, no. 2, pp. 58-63 (in Russian).

9. Deryushev, V.V., Sidelnikova, E.G. Analiz osnovnykh podkhodov k raschetu kompleksnogo pokazatelya, uchityvayushchego kachestvo stroitel'nykh i pod'emno-transportnykh mashin. [Analysis of the main approaches to the calculation of a complex indicator that considers the quality of construction and lifting and transport machines.] Stroitel'stvo. Dorogi. Transport: mat-ly mezhdunar. nauch.-prakt. konf. [Construction. Roads. Transport: materials of internat. sci.-pract. conf.] Rostov-on-Don, 2015, pp. 107-108 (in Russian).

10. Rogovenko, T.N., Zaytseva, M.M. Metod polucheniya sovokupnosti konechnogo ob'ema iz maloy vyborki s pomoshch'yu modelirovaniya. [Method of obtaining a set of finite volume of a small sample by modelling.] Dep. in VINITI, 2008, no. 970, V2008 (in Russian).

11. Deryushev, V.V., Artashesyan, A.A. Algoritm mashinnogo obucheniya na osnove analiza malykh vyborok. [Machine learning algorithm based on the analysis of small samples.] Stroitel'stvo i arkhitektura. Dorozhno-transportnyy fakul'tet: mat. mezhdunar. nauch.-prakt. konf. [Construction and architecture. Road transport faculty: mat. of internat. sci.-pract. conf.] Rostov-on-Don, 2017, pp. 82-86 (in Russian).

12. Kasyanov, V.E., Zaytseva, M.M. Otsenka parametrov raspredeleniya Weybulla dlya sovokupnosti konechnogo ob'ema. [Estimation of Weibull distribution parameters for the set of finite volume.] Dep. in VINITI, 2012, no. 21, V2012 (in Russian).

13. Deryushev, V.V., Sidelnikova, E.G. Prognozirovanie trebovaniy k kharakteristikam transportnykh agregatov s uchetom ekonomicheskikh ogranicheniy. [Prediction of performance requirements for transport units by considering the economic constraints.] Nauchnoe obozrenie, 2014, no. 9-3, pp. 888-890 (in Russian).

14. Deryushev, V.V., Sidelnikova, E.G. Issledovanie organizatsii provedeniya otsenki urovnya kachestva stroitel'nykh mashin i oborudovaniya. [Study of assessment organization of the level of quality of construction machinery and equipment.] Nauchnoe obozrenie, 2014, no. 11-3, pp. 778-781 (in Russian).

15. Rogovenko, T.N., Zaytseva, M.M. Analiz metodov opredeleniya gamma-protsentnykh znacheniy prochnostnykh kharakteristik. [Analysis of methods for determining the gamma percentile values of strength characteristics.] Dep. in VINITI, 2009, no. 201, V2009 (in Russian).

16. Rogovenko, T.N., Zaitseva, M.M. Statistical modeling for risk assessment at sudden failures of construction equipment. MATEC Web of Conferences "International Conference on Modern Trends in Manufacturing Technologies and Equipment, ICMTMTE 2017", 2017. p. 05014.

Received 01.11.2018
Submitted 01.11.2018
Scheduled in the issue 15.01.2019

Autors:

Deryushev Viktor Vladimirovich,
chief researcher, Don State Technical University, (1, Gagarin sq., Rostov-on-Don, 344000, Russia), doctor of techn. sciences,
deryushevv@mail.ru

Kosenko Evgeniy Evgenyevich,
associate professor, Don State Technical University, (1, Gagarin sq., Rostov-on-Don, 344000, Russia), candidate of techn. sciences,
A123lok@mail.ru

Kosenko Vera Viktorovna,
Associate professor, Don State Technical University, (1, Gagarin sq., Rostov-on-Don, 344000, Russia), candidate of techn. sciences,
kosenko_verav@mail.ru

Zaytseva Marina Mikhaylovna,
associate professor, Don State Technical University, (1, Gagarin sq., Rostov-on-Don, 344000, Russia), candidate of techn. sciences,
marincha1@rambler.ru

UDC 62-781
DOI 10.23947/2541-9129-2019-2-58-61

ACCOUNTING OF FIRES AND THEIR CONSEQUENCES IN THE RUSSIAN FEDERATION IN 2019

Poddubnyy E. N., Struzhenkov A. N.
State Fire Academy of EMERCOM of Russia, Rostov-on-Don, Russian Federation

The article considers an actual problem of accounting of fires and their consequences. Based on the analysis of international experience and normative documents, it shows that the existing norms do not meet the modern requirements of legislative acts and require significant updating. The article provides the main ways and directions of normative documents updating for their efficiency and compliance with the legislation.

Keywords: fire safety, fire, regulatory requirements adjustment, supervisory activities, fire accounting.

УДК 62-781
DOI 10.23947/2541-9129-2019-2-58-61

УЧЕТ ПОЖАРОВ И ИХ ПОСЛЕДСТВИЙ В РОССИЙСКОЙ ФЕДЕРАЦИИ В 2019 ГОДУ

Поддубный Е. Н., Струженков А. Н.
Академия государственной противопожарной службы МЧС России, г. Ростов-на-Дону, Российская Федерация

В статье рассмотрена актуальная проблема учета пожаров и их последствий. На основе анализа международного опыта и содержания нормативных документов показано, что существующие нормы не отвечают современным требованиям законодательных актов и требуют существенного усовершенствования. Приведены основные пути и направления совершенствования нормативных документов с целью их эффективности и соответствия законодательству.

Ключевые слова: пожарная безопасность, загорание, корректировка нормативных требований, надзорная деятельность, учет пожаров.

Introduction. The Russian Federation has a unified state system of statistical recording of fires and their consequences. The State Fire-Fighting Service maintains official statistical records and state statistical reports on fires and their consequences. The EMERCOM of Russia [1] determines the recording of fires and their consequences.

Since January 1, 2019, the amended recording of fires and their consequences has been working on the territory of the Russian Federation. The previous procedure was valid for ten years [2].

Significant changes are the abandonment of the term "catching fire" and the change in the order of accounting for injured and dead people in the fire.

Let us consider in depth the change in the order of recording of fires.

The definition of the term "catching fire" is given in GOST 12.1.033–81 "Occupational Safety Standards (SSBT). Fire Safety. Terms and Definitions". Catching fire — an uncontrolled burning outside a special furnace, without damage [3, 4].

The problem of updating the regulatory requirements for safety has been the subject of research for many years [5]. Largely practice of supervision was based on normative materials of the USSR; it was not a scientifically sound analysis. As a result, the existing methods do not contain special calculations of risk assessment and factors determining the probability of fires and heat flux intensity.

The analysis of the existing calculation methods for determining the time of safe evacuation of people was carried out in [6]. The author corrects the method of calculating the evacuation time taking into account the minimum distance to the fire load and convincingly shows that this allows you to increase the level of safety of people in case of fire and ensure their timely evacuation.

An important step is fire analysis and the reconstruction of its initial stage. In [7] there was developed the algorithm for reconstruction of the fire initial stage to determine the time of the fire, the place of

the fire and the type of the fire load. The algorithm is based on numerical simulation of fire processes and application of the software complex "Fo-gard-NV (field model)". The results of the work allowed the authors to properly assess violations of fire safety requirements aimed at preventing fire occurrence.

The analysis of fires occurrence factors taking into account their probabilistic nature is carried out in [8]. Stochastic model of reaching the critical temperature under the influence of heat is based on the deterministic model taking into account the probabilistic nature of the heat flow. The approach proposed by the authors, based on the theory of random processes, allows analyzing basic regularities according to the mathematical expectations of the parameters characterizing the flame bush, as well as to build the confidence boundaries of the main trend.

Problem statement.

The problem of occurrence and recording of fires, analysis and prediction of their consequences is a global problem [9]. International organizations at various levels set the task of adequate assessment of the current parameters of fire danger in the world as a whole. At the same time, the normative documents regulating the fires recording are far from perfect.

Up to 01.01.2019 the cases of burning were recorded as catching fires (regardless of the causes of its occurrence), which did not spread to other objects of protection: abandoned buildings and vehicles; dry grass; poplar fluff; peat on lawns and home gardens; crop residue; stubble; garbage in landfills, vacant lots, on the territory of households, on roadsides, on container sites for its collection, in containers (boxes) for its collection, in elevator shafts (elevators) of residential buildings, in garbage bins of residential buildings, on stairwells of residential buildings, in basements and attics of residential buildings [2]. In other words, the conditions for the definition of "catching fire" were fulfilled [3].

The term "fire" is defined by Federal Law of 21.12.1994 No. 69-FZ (ed. of 30.10.2018) "On Fire Safety" (hereinafter - Federal Law No. 69-FZ). Fire — the uncontrollable burning causing material damage, harm to life and health of citizens, interests of society and the state [1].

Since January 2019, the difference between "catching fire" and "fire" has ceased to exist, and all cases are called "fire".

In the spring of each year in all of Russia a popular "fun" of the population begins— the burning of dry grassy vegetation. The quantity, size and effects of this phenomenon are directly related to weather conditions: the height of the snow cover in winter, the number and frequency of precipitation in the form of rain after snow cover melting, the number of dry and windy days, night air temperatures, etc.

Unfortunately, the spring of 2019 was no exception. The number of the registered fires of dry grassy vegetation in March - April this year in the territory of many subjects of the Russian Federation amounted to several thousand cases. In accordance with the requirements of the Order of EMERCOM of Russia of 21.11.2008 No. 714 (ed. of 08.10.2018) "On approval of the recording of fires and their consequences" (hereinafter –Order No. 714) all fires are included in the statistical record as fires. There is an increase in the number of fires in the tens and hundreds of times.

The introduction of changes in the recording procedure for fires from January 1, 2019 is a controversial and unjustified decision.

First, the provisions of Federal Law No. 69-FZ regarding the presence of material damage, harm to the life and health of citizens, the interests of society and the state in case of fire are not fulfilled. It does not take into account material damage and harm to the interests of society and state, for example, burning of dried grass or reed grass on the area of a few hectares outside the settlements, poplar fluff along the sidewalk in the settlements.

Second, to assess the situation with fires in a single area at the present time it is necessary to enter in the analysis more rows (data) and divide fires on objects of economy and fires associated with the burning of dry grass, garbage, etc.

Third, the application of the current fire recording procedure increases the burden on the employees of the Federal State Fire Supervision due to the need to fill in the full fire record card. The time you spend filling in the dry grass fire record card (burning of garbage, etc.), has increased at least in three times [1, 2].

Fourthly, many management decisions made on the basis of the "old" and "new" fire statistics will be radically different from each other.

These are only a few of the negative phenomena associated with the changes in the order of fires and their consequences recording. The adjustment of these documents is a further important task to improve the regulatory framework for fire recording.

Conclusion. Based on the analysis of modern normative documents, international experience and literature, it is shown that the new normative documents of fire registration and their consequences do not meet modern requirements of the legislative framework and need to be adjusted. The paper shows the main directions of improving the regulatory framework, such as accounting for material damage and risks to life and health of citizens, taking into account the increase in the load on Supervisory bodies staff, taking into account the differences in the "old" and "new" statistics of fires and their impact on management decisions.

References

1. Prikaz MCHS Rossii ot 26.12.2014 No. 727 "O sovershenstvovanii deyatel’nosti po formirovaniyu elektronnykh baz dannykh ucheta pozharov (zagoraniy) i ikh posledstviy". [Order of EMERCOM of Russia of 26.12.2014 No. 727 "On improvement of activity on formation of electronic databases of fire (catching fire) and its consequences".] Elektronnyy fond pravovoy i normativno-tekhnicheskoy dokumentatsii. [Electronic fund of legal and normative-technical documentation.] Available at: http://docs.cntd.ru/document/420303797 (accessed: 01.03.2019) (in Russian).

2. Prikaz MCHS Rossii ot 21.11.2018 No. 714 (red. ot 08.10.2018) "Ob utverzhdenii Poryadka ucheta pozharov i ikh posledstviy (s izmeneniyami na 8 oktyabrya 2018 goda)". [Order of EMERCOM of Russia of 21.11.2008 No. 714 (ed. of 08.10.2018) "On approval of the Recording procedure for fires and their consequences (as amended on 8 October 2018)".] Elektronnyy fond pravovoy i normativno-tekhnicheskoy dokumentatsii. [Electronic fund of legal and normative-technical documentation.] Available at: http://docs.cntd.ru/document/902133628 (accessed: 01.03.2019) (in Russian).

3. Prikaz MCHS Rossii ot 24.12.2018 No. 625 "O formirovanii elektronnykh baz dannykh ucheta pozharov i ikh posledstviy". [Order of EMERCOM of Russia dated 24.12.2018 № 625 "On the formation of electronic databases of fire registration and its consequences".] Elektronnyy fond pravovoy i normativno-tekhnicheskoy dokumentatsii. [Electronic fund of legal and normative-technical documentation.] Available at: http://docs.cntd.ru/document/552366056 (accessed: 01.03.2019) (in Russian).

4. Federal’nyy zakon ot 21.12.1994 No. 69-FZ "O pozharnoy bezopasnosti (s izmeneniyami na 30 oktyabrya 2018 goda)". [Federal law of 21.12.1994 No. 69-FZ "On Fire Safety (as amended on 30 October 2018)".] Elektronnyy fond pravovoy i normativno-tekhnicheskoy dokumentatsii. [Electronic fund of legal and normative-technical documentation.] Available at: http://docs.cntd.ru/document/9028718 (accessed: 01.03.2019) (in Russian).

5. GOST 12.1.033-81 Sistemy standartov bezopasnosti truda (SSBT). Pozharnaya bezopasnost’. Pozharnaya bezopasnost’. Terminy i opredeleniya (s Izmeneniem No. 1). [GOST 12.1.033-81 Occupational safety standards system (SSBT). Fire safety. Fire safety. Terms and definitions (with Amendment No. 1).] Elektronnyy fond pravovoy i normativno-tekhnicheskoy dokumentatsii. [Electronic fund of legal and normative-technical documentation.] Available at: http://docs.cntd.ru/document/1200003841 (accessed: 02.03.2019) (in Russian).

6. Kozlachkov, V.I. etc. Aktualizatsiya normativnykh trebovaniy v oblasti pozharnoy bezopasnosti s uchetom risk-orientirovannogo podkhoda v nadzornoy deyatel'nosti. [Updating of regulatory requirements in the field of fire safety taking into account the risk-based approach in Supervisory activities.] Tekhnologii tekhnosfernoy bezopasnosti. Scientific electronic library ELibrary.ru. Available at: https://elibrary.ru/item.asp?id=26249905 (accessed: 02.03.2019) (in Russian).

7. Yagodka, E.A. Korrektirovka metodik otsenki pozharnogo riska s uchetom teplovogo potoka pozharov. [Adjustment of fire risk assessment methods taking into account fires heat flux.] Tekhnologii tekhnosfernoy bezopasnosti. Scientific electronic library ELibrary.ru. Available at: https://elibrary.ru/item.asp?id=20356645 (accessed: 03.03.2019) (in Russian).

8. Lobaev, I.A., Vechtomov, D.A., Pleshakov, V.V. Rekonstruktsiya nachal'noy stadii pozhara s uchetom parametrov sistemy obnaruzheniya opasnykh faktorov pozhara. [Reconstruction of the fire initial stage taking into account the parameters of the fire hazard detection system.] Tekhnologii tekhnosfernoy bezopasnosti. Scientific electronic library ELibrary.ru. Available at: https://elibrary.ru/item.asp?id=36474425 (accessed: 03.03.2019) (in Russian).

9. Abramov, Yu.A., Basmanov, A.E. Stokhasticheskaya model' nagreva rezervuara s nefteproduktom pod teplovym vozdeystviem pozhara. [Stochastic model of heating of the reservoir with oil under heat influence of fire.] Pozharovzryvobezopasnost', 2007, vol. 16, no. 4, pp. 37-43 (in Russian).

10. Peltikhina, S.V., Bazhenova, L.M. Statistika pozharov. Vliyanie tekushchikh parametrov na obstanovku s pozharami. [Statistics of fires. The influence of current parameters on the situation with fires.] Vestnik of Voronezh Institute of High Technologies, 2017, no. 4 (23), pp. 32-35 (in Russian).

Received 01.11.2018
Submitted 01.11.2018
Scheduled in the issue 15.01.2019